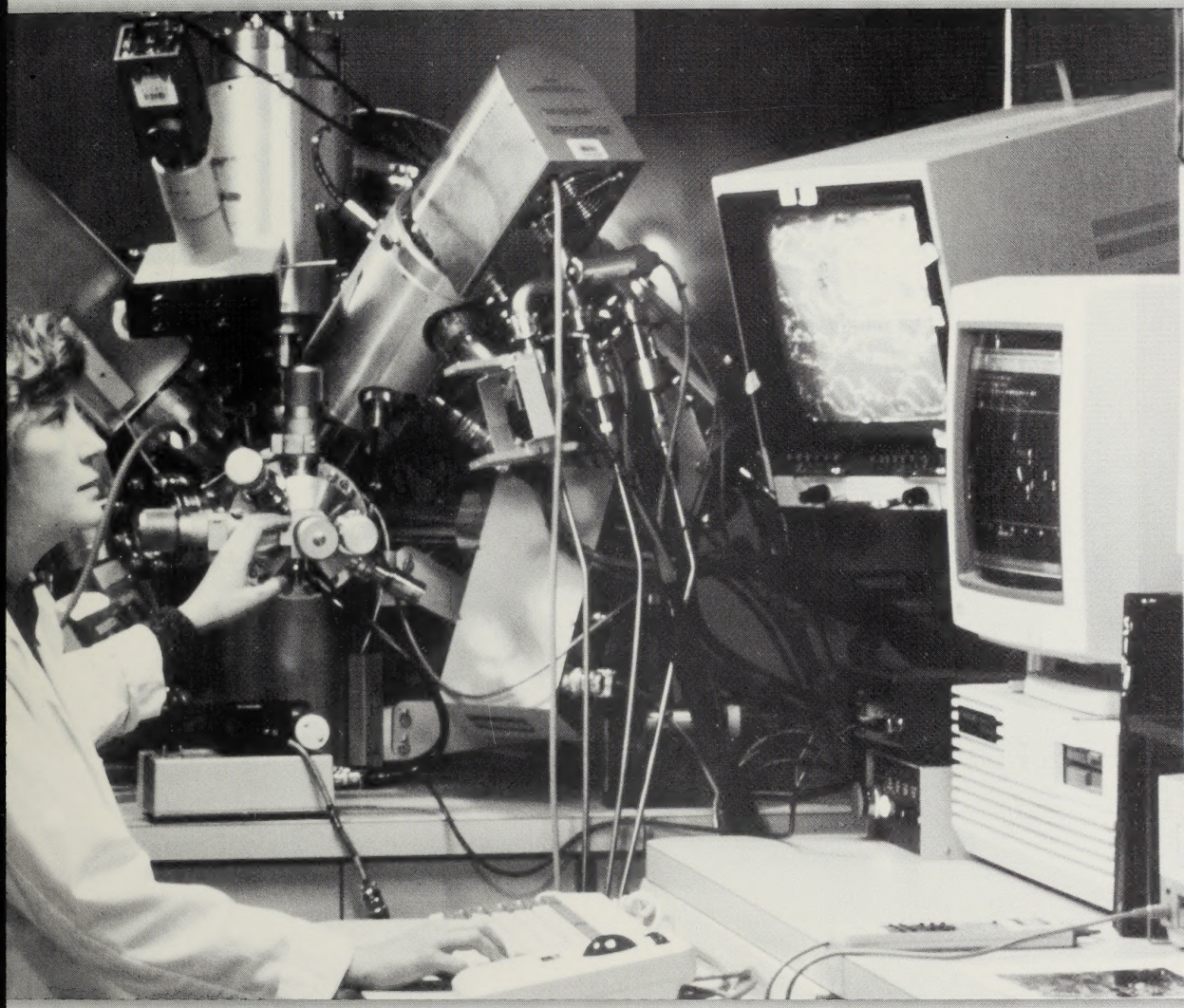
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Science 20



MODULE 5

Solution Chemistry

Distance Learning

Alberta EDUCATION

Science 20

Module 5

Solution Chemistry

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Science 20
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Module 5
Solution Chemistry
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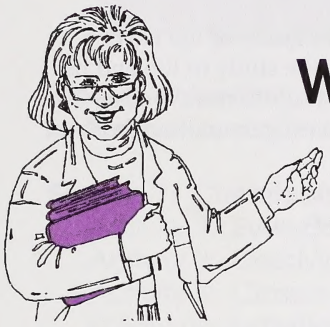
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Welcome to Module 5!

We hope you'll enjoy your study of Solution Chemistry.

To make your learning a bit easier, watch the referenced videocassettes whenever you see this icon.



When you see this icon, study the appropriate pages in your textbook.



Good Luck!

COURSE OVERVIEW

This course contains eight modules. Modules 1 and 2 involve the study of the Earth's physical features and past life history. Modules 3 and 4 involve the study of life and its interaction with the Earth. Modules 5 and 6 involve the study of solutions as well as how chemistry is used for everyday things. Modules 7 and 8 investigate motion, both on Earth and in space.

The module you are working on is highlighted in a darker colour.

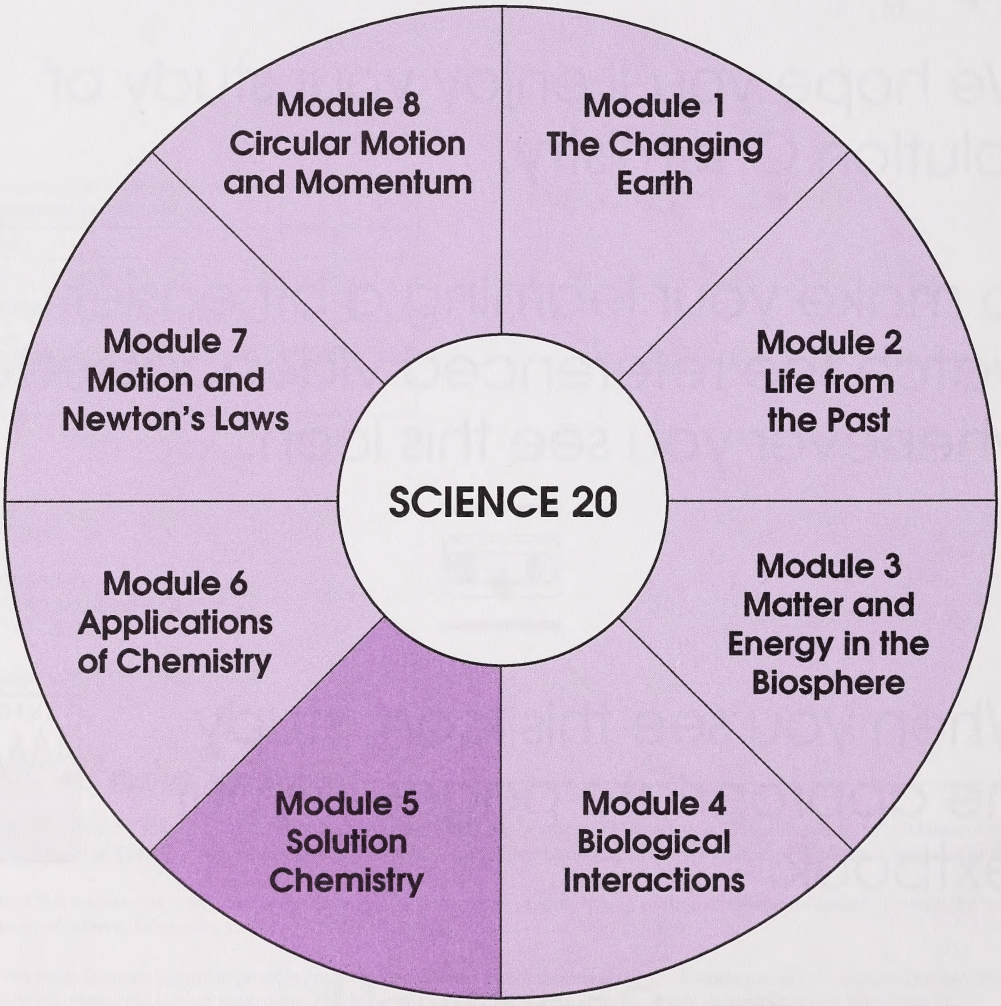


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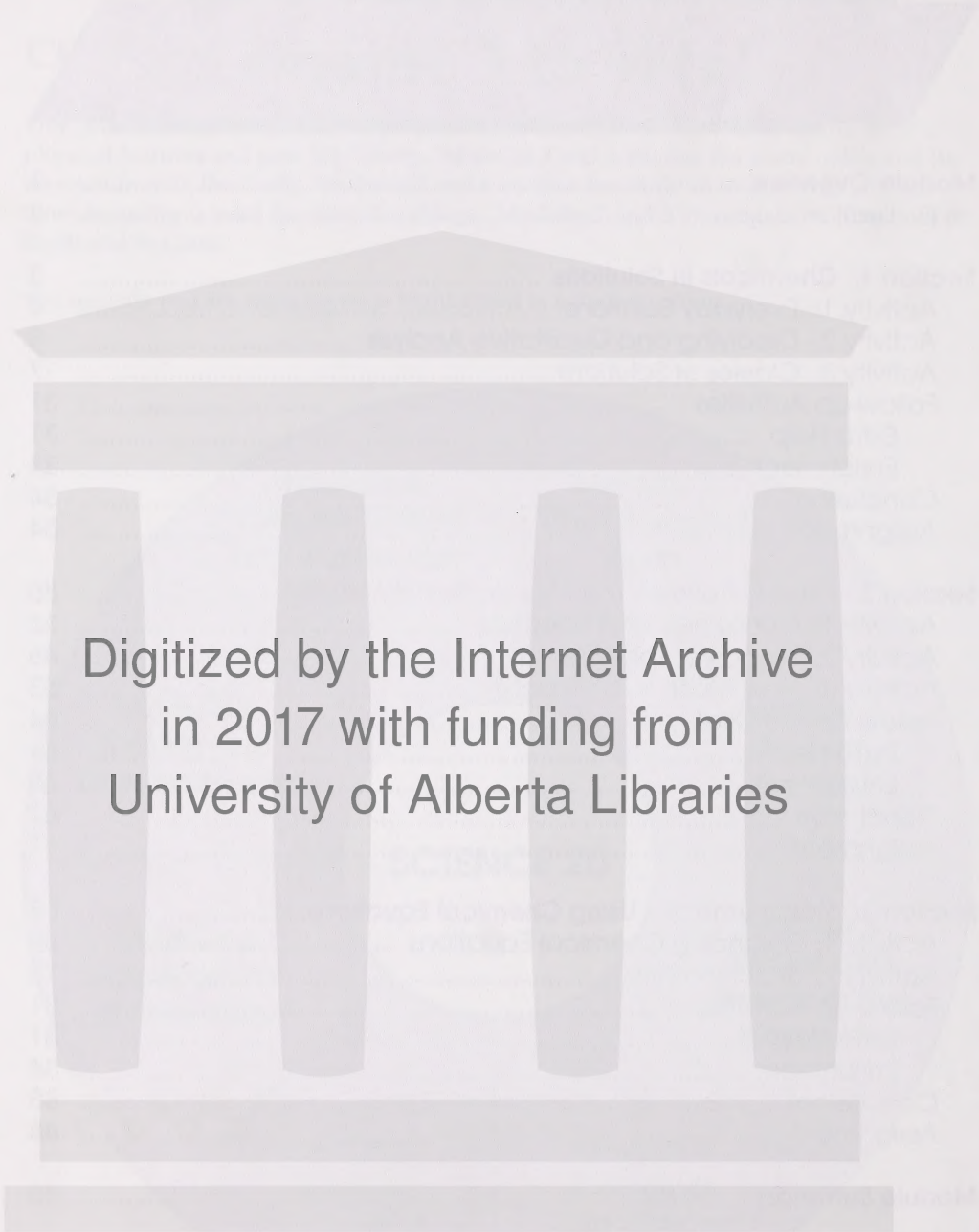
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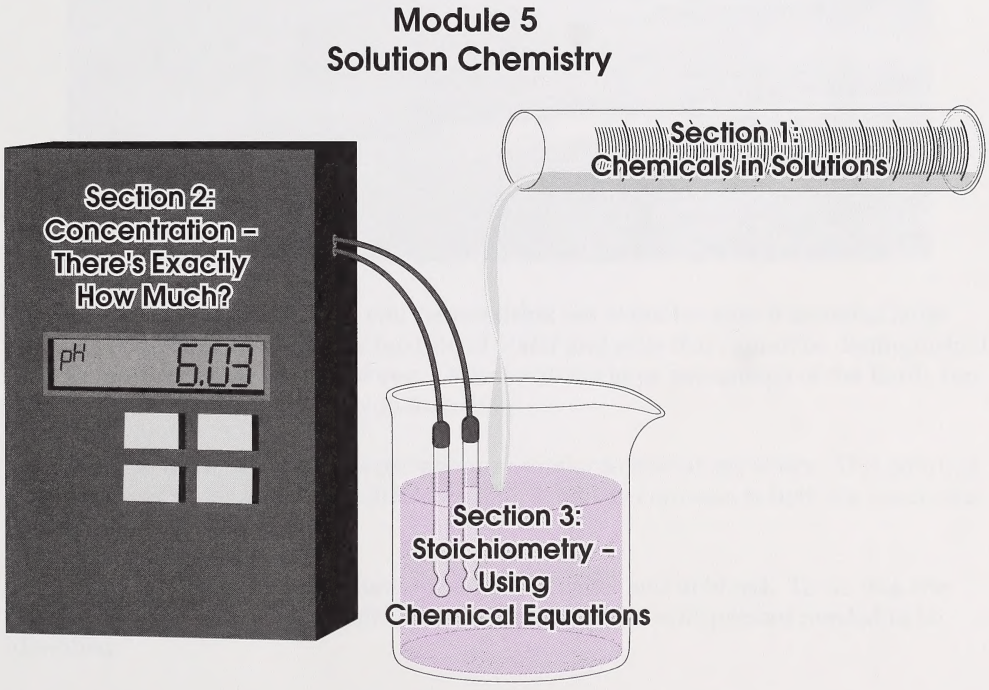
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MODULE OVERVIEW

Do you remember those hot, dry summer days when you went to the refrigerator for something cool to quench your thirst? You accidentally tip over a bottle of pop as you are reaching for it way in the back of the refrigerator; then you take it out to pour yourself a large glass. When you open the bottle, what do you see happening to the pop? It bubbles, foams, and makes it difficult to fill your glass.

The escaping gas is one of the reasons why you drink pop. The carbon dioxide gives the tingle in your mouth when you drink it. If all the gas escapes, then the pop loses some of its tingle. The pop you drink is not one substance but a mixture of substances known as a solution.

In this module you will study solutions and learn to describe solutions based on their contents and how they react. You will also learn to predict how much of a solution will react with another solution, or how much of a chemical can be produced when different solutions react.



Evaluation

Your mark in this module will be determined by your work in the Assignment Booklet. You must complete all assignments. In this module you are expected to complete three section assignments. The assignment breakdown is as follows:

Section 1 Assignment	**25 marks**
Section 2 Assignment	**40 marks**
Section 3 Assignment	**35 marks**
TOTAL	**100 marks**

Section

1



There are oceans all around, yet you cannot drink sea water because it contains large amounts of different salts. It is a mixture of water and salts that cannot be distinguished from pure water using the naked eye. Oceans cover a large percentage of the Earth, but saltwater mixtures are closer to you than that.

Your blood is made up of a saltwater solution similar to that of sea water. This solution is a mixture of water and many different salts. Some are common to both the ocean and your blood.

Chemists have discovered the composition of sea water and of blood. To do this, the type of salts, the nature of the salts, and the amount of the salts present needed to be identified.

In this section, you will learn what solutions are; then you will describe different types of solutions. You will see how a reaction between two solutions can be used to discover the nature of the solution.

Activity 1: Everyday Solutions

Do you know you are using solutions every day? Many common substances are solutions. The following is a list of things that you might come into contact with throughout the day.

- baking soda
- latex paint
- table sugar
- pop
- cup of tea
- tap water
- bread
- table salt

1. Which items in the previous list are combinations of more than one substance or mixtures?

2. Of these mixtures, which ones appear to be the same throughout, with no obvious ingredients or parts to them?

Check your answers by turning to the Appendix, Section 1: Activity 1.

homogeneous mixtures – combinations of substances that produce a uniform appearance

heterogeneous mixtures – combinations of substances that have layers or separations

solvent – the substance in a solution present in the greatest amount

solute – the substance in a solution present in the least amount

The three items mentioned in the answer to question 2 that appear to be uniform throughout are **homogeneous mixtures**. Homogeneous mixtures are solutions. It is a common misconception that a solution is made up solely of water and something else. This is not so. Homogeneous mixtures of any substances in any state are solutions. For example, stainless steel, air, and gasoline are solutions.

Latex paint has layers if it has not been recently stirred. Bread has a different makeup on the outside compared to the inside. These are examples of **heterogeneous mixtures**. Other examples of mixtures that do not form solutions are oil and vinegar dressing and chocolate chip cookies.

The parts of a solution are named according to how much of the ingredient is present compared to all the others. If it is the major ingredient, then it is called the **solvent**. If it is any other ingredient, then it is called the **solute**.



Now that you have reviewed some basic definitions, read Properties of Solutions on pages 240 and 241 of *Visions 2*.

3. What is a solution?

4. What forms (states of matter) can a solution be in?

5. What is an aqueous solution?

6. Using the information that describes Photo 7.1 on page 241 of your textbook, identify the solute and the solvent for the following three solutions. Set up a chart like the following:

Solution	Solute	Solvent
antifreeze		
solder		
pop		

Check your answers by turning to the Appendix, Section 1: Activity 1.

Since water is the most common solvent available, most solutions are aqueous solutions. But the availability of water is not the only reason for using aqueous solutions in chemical reactions.

VISIONS

To find out how water is involved in chemical changes in living and non-living systems, read pages 242 and 243 of your textbook.

7. List three examples in living systems that use water as a solvent and three examples in non-living systems that use water as a solvent.

8. List four examples of chemical substances that can dissolve and be detected in ground water.

9. What agency sets standards for testing the water you drink?

Check your answers by turning to the Appendix, Section 1: Activity 1.

Since many chemical substances readily enter the water cycle, you must take care when you use chemical substances that dissolve to form aqueous solutions. WHMIS can be used to ensure the proper disposal and handling of the chemicals. Do you recall WHMIS from Science 10?

VISIONS

10. What does WHMIS stand for? If you cannot remember, check page 543 of your textbook.

There are eight possible WHMIS symbols that can be used. They are shown in Table 5.1 along with the class letters and the descriptions.

TABLE 5.1 THE EIGHT WHMIS LABELS

Symbol	Class Letter	Description
	Class A:	Compressed gas
	Class B:	Flammable and combustible material
	Class C:	Oxidizing material
	Class D-1:	Material causing immediate and serious toxic effects
	Class D-2:	Material causing other toxic effects
	Class D-3:	Biohazardous infectious material
	Class E:	Corrosive material
	Class F:	Dangerously reactive material

Note: The class letters A to H may be used in some sources of information.

11. Check the descriptions for each symbol in Table 5.1. From the list of class letters, which do you think could apply to aqueous solutions used in high school labs?

12. All controlled products sold by chemical supply companies come with a Material Safety Data Sheet like the one that follows. Why do you think this is sent with the chemical?

Altachem

Altachem Industries Inc.
42 Centre Street N.W.
Red Deer, Alberta
T6Q 7H8
Tel (403) 555-8386
Fax (403) 555-6628

Material Safety Data Sheet
24 hour emergency number
Canutec: (403) 555-6776

Product Name: SODIUM BICARBONATE

Sold to:

Data Sheet No.: 74659-3
Prepared: 04/28/92
Supersedes:
Prepared by: Richard Tarasgard

1. Product Identification

Synonym or Generic ID: ATC-4326, ATC-6298
DOT Hazard Classification:
UN# (PIN):
WHMIS Class:

Formula: $NaHCO_3$
Molecular Wt: 84.01

2. Components

Ingredients	CAS	% (by wt.)	PEL	TLV	Hazard
Sodium bicarbonate	144-55-8	99.7	n/av	n/av	

3. Physical Properties

Physical State: solid
Odour Threshold: n/av
Melting Point: decomposes @ 228°F
Boiling Point: n/ap
Vapour Pressure: n/av
Evaporation Rate: n/av (n-Butylacetate = 1)
Appearance/Odour: odourless white crystalline powder

Specific Vapour Density: n/av
Specific Gravity: 2.20 (H_2O = 1)
Solubility in H_2O: moderate
Coeff. H_2O/Oil: n/av
Percent Volatile: n/av
pH: n/av

4. Fire and Explosion Hazard Data

Flash Point: none Flammable Limits: LEL n/ap UEL n/ap Autoignition: n/av
Explosion Data: n/av
Extinguishing Media: water spray, dry chemical, foam
Hazardous Combustion Products: oxides of carbon and sodium

Firefighting Procedures: Use self-contained breathing apparatus with a full facepiece operated in a pressure demand or other positive pressure mode. Use extinguishing media appropriate to the surrounding fire conditions.

Special Fire and Explosion Hazards: emits toxic fumes under fire condition

FIGURE 5.1 Example of a Material Safety Data Sheet

13. When working with a chemical, what information from WHMIS labels and Material Safety Data Sheets do you need?

Check your answers by turning to the Appendix, Section 1: Activity 1.

Aqueous solutions are the most common type of homogeneous mixtures. When working with solutions in a lab, they must be handled carefully and disposed of properly. In the next activity, you will learn the importance of the solute and how it dissolves in water to form an aqueous solution.

Activity 2: Dissolving and Qualitative Analysis



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Why do some substances dissolve and others do not? If your body were made up of substances that dissolve, what might happen to you if you jumped into a swimming pool and went for a swim? Fortunately, the components of your skin will not dissolve in water; thus, you stay intact. Some substances dissolve well in water.

1. The following is a list of some substances with which you are familiar. Copy the list and check (✓) the solutes you think will dissolve easily in water.

- table salt
- cooking oil
- baking soda
- sand
- laundry soap
- steel wool
- headache tablet
- table sugar

VISIONS

Many of the substances in your home that dissolve easily in water are a certain kind of compound. Read pages 243 to 245 of *Visions 2* to discover what types of compounds dissolve the best and how they form aqueous solutions.

2. What are the names of the two types of compounds that usually dissolve easily in water?

3. Before $NaI_{(s)}$ and $Pb(NO_3)_{2(s)}$ react, each is dissolved in water. What will form when each of these solids are dissolved?

4. What property of water allows it to free the ions in an ionic compound?

5. Based on the information from Figure 7.3A on page 245 of your textbook, describe how ions are formed during the dissolving process.

6. Describe how molecular compounds dissolve using the information from Figure 7.3B on page 245 of your textbook.

7. Describe one similarity and one difference in the dissolving processes of ionic and molecular compounds in water.

8. Why do nonpolar, molecular compounds form layers rather than dissolving in water?

9. What do you need to know about substances before you can predict whether or not they will dissolve?

10. In the Did You Know part near the bottom of page 244 of your textbook, it is mentioned that some compounds such as calcium chloride have such a strong attraction for water that they absorb water from the air. Such a compound is a drying agent and is called a desiccant. Can you think of one place where a desiccant would be used? Why is it used?

Check your answers by turning to the Appendix, Section 1: Activity 2.

diluted – having a lesser amount of dissolved solute

concentrated – having a greater amount of dissolved solute

You have learned that ionic compounds and polar covalent compounds dissolve well in water because the attraction to water molecules is greater than the attraction between the particles (ions or molecules) of compounds. Dissolving may look as if it has a definite start and end to it, but this is not necessarily so.

The duration of dissolving depends on the relative amount of solute present. One way scientists describe relative amounts of solute is by using the terms **diluted** and **concentrated**. Relative amount is a way of saying that you use these terms when you compare solutions to each other. You may have done this by tasting the relative amounts of dissolved solutes in sweetened tea.

Figure 5.2 shows two solutions. You can say that Solution A is more concentrated than Solution B because Solution A has more solute in it than Solution B.

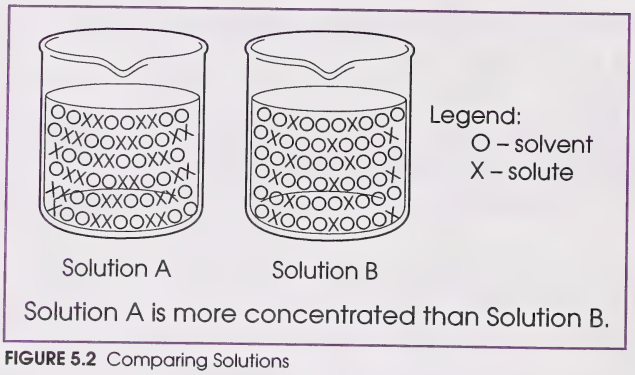


FIGURE 5.2 Comparing Solutions

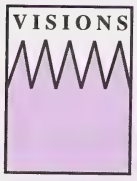
11. You have two cups of tea. How would you describe the sweetest one using chemical terms?

Check your answers by turning to the Appendix, Section 1: Activity 2.

saturated solution – a solution that can dissolve no more solute at a given temperature

Another method used to describe the amount of dissolved solute in a solution is in terms of its saturation. Have you ever had a cup of tea and noticed sugar on the bottom of the cup after you drank some? Although the sugar was dissolved at the start, some has recrystallized. The tea has cooled and become a **saturated solution**.

12. Can you see what happens in the tea as the sugar dissolves or recrystallizes?



To find out what really happens in a saturated solution, read the section Solutions Exist in a Dynamic Equilibrium on pages 245 and 246 of *Visions* 2.

13. According to Figure 7.4, what type of solution, saturated or unsaturated, has an on-going cycle of dissolving and recrystallizing?

14. What balances the rate of dissolving in a saturated solution?

15. Why can't you see the solute dissolving and recrystallizing?

Check your answers by turning to the Appendix, Section 1: Activity 2.

dynamic equilibrium – a steady state that occurs in a closed system when two opposite changes happen at the same rate

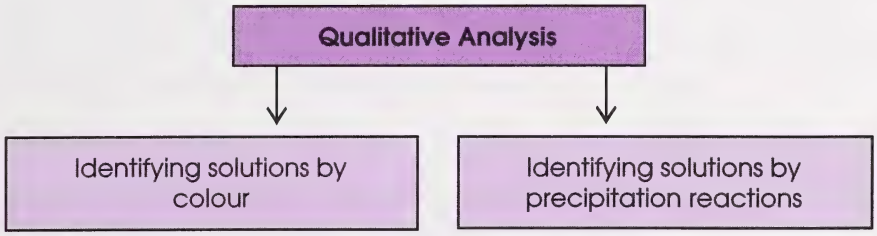
Saturated solutions are in a state of **dynamic equilibrium**. The solute is continuously dissolving and recrystallizing. You cannot see this happening because it is dissolving and recrystallizing at an atomic or molecular level, and the rates of the two processes are equal.

qualitative analysis – any method used to determine the identity of a substance

quantitative analysis – a method used to determine how much of substance is in a sample

In the section introduction, the idea of discovering the type and the amounts of compounds in sea water or plasma was introduced. To do this, chemists use qualitative and quantitative analysis. The **qualitative analysis** of a solution refers to the identity or type of solute dissolved. The **quantitative analysis** of a solution refers to the amount of the solute dissolved in the solvent.

In the remainder of this activity, you will be focusing on qualitative analysis. In Section 2 you will work with quantitative analysis. The following graphic outlines the remainder of Activity 2.



Before you can identify a solution by its colour, you must know the colours of various ions. Table 5.2 shows the colours of various aqueous ions. If the ion is not listed in the table, then assume that it has no colour.

TABLE 5.2 THE COLOURS OF AQUEOUS IONS

Name	Formula	Colour	Name	Formula	Colour
chromate	CrO_4^{2-}	yellow	dichromate	$Cr_2O_7^{2-}$	orange
chromium (III)	Cr^{3+}	green	iron (III)	Fe^{3+}	pale yellow
chromium (II)	Cr^{2+}	blue	iron (II)	Fe^{2+}	pale green
cobalt (II)	Co^{2+}	pink	manganese (II)	Mn^{2+}	pale pink
copper (II)	Cu^{2+}	blue	nickel (II)	Ni^{2+}	green
copper (I)	Cu^{+}	green	permanganate	MnO_4^{-}	purple

16. You are given two solutions to identify. Solution A is bright yellow and Solution B is a dark purple. You have been told that the solutions could be either $Cu(NO_3)_{2(aq)}$, $K_2Cr_2O_{7(aq)}$, $KMnO_{4(aq)}$, or $Na_2CrO_{4(aq)}$. What is the identity of Solution A and Solution B?

17. You are given three solutions: A, B, and C. Their colour properties are given in the following chart.

Solution	Colour
A	pink
B	colourless
C	blue

Identify each solution as either $NaNO_{3(aq)}$, $Fe(NO_3)_{2(aq)}$, $Co(NO_3)_{2(aq)}$, or $Cr(NO_3)_{2(aq)}$.

Check your answers by turning to the Appendix, Section 1: Activity 2.

What happens when you are given two solutions of the same colour or even two colourless solutions? How do you determine the identity of the solutes?

The colour of the solute is often used with other qualitative methods. One method to determine the type of solute in a solution is to react it with one, two, or three other solutions to see if a **precipitate** forms.

precipitate – a solid formed when two aqueous solutions react

When two solutions are mixed and a precipitate forms, the new solution is saturated with respect to the precipitate solute. This means that the precipitate formed does not dissolve as easily as each of the two solutes that reacted to form it. For example, look at the following reaction:

$$\underset{\text{colourless solution}}{2NaI_{(aq)}} + \underset{\text{colourless solution}}{Pb(NO_3)_{2(aq)}} \rightarrow \underset{\text{colourless solution}}{2NaNO_{3(aq)}} + \underset{\text{bright yellow solid}}{PbI_{2(s)}}$$

The sodium iodide solution $\left(NaI_{(aq)}\right)$ and the lead(II) nitrate solution $\left(Pb(NO_3)_{2(aq)}\right)$ are unsaturated solutions. The lead(II) iodide $\left(PbI_{2(s)}\right)$ is the precipitate that is formed. This means that $NaI_{(s)}$ and $Pb(NO_3)_{2(s)}$ are more soluble (better dissolvers) than $PbI_{2(s)}$.

soluble – capable of being dissolved

insoluble – incapable of being dissolved completely

Therefore, if a compound dissolves in water to form an unsaturated solution, it is said to be **soluble**. If it does not dissolve completely, then it is **insoluble**. How much of a substance dissolves also depends on other factors such as the ratio of solute to solvent and temperature of the solution.

solubility – how well a substance dissolves

Solubility is another term which you will see in relation to dissolving compounds. Substances that dissolve easily in water have a high solubility. Common table salt $\left(NaCl_{(s)}\right)$ has a high solubility, and chalk $\left(CaCO_{3(s)}\right)$ has a low solubility. Solubility can be used to compare one solute to another.

solubility table – a chart used to predict whether an ionic compound is soluble or insoluble

By performing many reactions that form precipitates, you can find out how well a solute dissolves compared to others. Experiments of this kind have been performed many times, and the ionic solutes that have a high solubility have been separated from the solutes that have a low solubility. These results have been placed on a **solubility table**.

Recall from Science 10 that you can predict whether an ionic compound is soluble or insoluble based on information such as that which is summarized in the solubility table found on page 548 of *Visions 2* in Appendix D.

VISIONS

An example of a compound that has low solubility in water is calcium sulphate. If you check the solubility table, the calcium ion $\left(Ca^{2+}\right)$ is found under the sulphate ion $\left(SO_4{}^{2-}\right)$ and is listed as having low solubility.

An example of a compound that has high solubility in water is calcium acetate. If you check the solubility table, the calcium ion $\left(Ca^{2+}\right)$ falls into the category of most when it is under the acetate ion $\left(CH_3COO^-\right)$. This means that most ions that combine with CH_3COO^- are listed as having high solubility. If you are unable to find an ion in the solubility table, find its group number in the periodic table on page 247 of Visions 2; then find the group number in the solubility table.

VISIONS

18. Draw and complete a chart similar to the one that follows. Using the periodic table and the solubility table on pages 547 and 548 of your textbook, describe the solubility of each ionic solute listed.

Name	Formula	High or Low Solubility
sodium nitrate	$NaNO_{3(s)}$	
barium chloride	$BaCl_{2(s)}$	
lead (II) hydroxide	$Pb(OH)_{2(s)}$	
ammonium phosphate	$(NH_4)_3PO_{4(s)}$	
barium sulphide	$BaS_{(s)}$	
calcium carbonate	$CaCO_{3(s)}$	

VISIONS

To summarize qualitative analysis, read from the middle of page 246 to Activity 7.1 on page 248 of *Visions 2*.

19. List four ways that colour can indicate the identity of a substance.

Check your answers by turning to the Appendix, Section 1: Activity 2.

Investigation: Identifying Ions in Aqueous Solutions

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

Background Information



Step 1: Read Activity 7.1 on pages 248 to 250 of *Visions* 2 entirely to familiarize yourself with this investigation.

Step 2: Before doing the investigation, answer question 20.

The following are balanced, double replacement equations for the reactions between each ammonium solution and each acetate solution that you will be studying in this investigation. The indication as to whether the products are aqueous or whether a precipitate has formed has been left off.

$$Ca(CH_3COO)_{2(aq)} + (NH_4)_2CO_{3(aq)} \rightarrow CaCO_3 + 2NH_4CH_3COO$$

$$Ca(CH_3COO)_{2(aq)} + (NH_4)_2SO_{4(aq)} \rightarrow CaSO_4 + 2NH_4CH_3COO$$

$$Ca(CH_3COO)_{2(aq)} + 2NH_4OH_{(aq)} \rightarrow Ca(OH)_2 + 2NH_4CH_3COO$$

$$Mg(CH_3COO)_{2(aq)} + (NH_4)_2CO_{3(aq)} \rightarrow MgCO_3 + 2NH_4CH_3COO$$

$$Mg(CH_3COO)_{2(aq)} + (NH_4)_2SO_{4(aq)} \rightarrow MgSO_4 + 2NH_4CH_3COO$$

$$Mg(CH_3COO)_{2(aq)} + 2NH_4OH_{(aq)} \rightarrow Mg(OH)_2 + 2NH_4CH_3COO$$

$$Sr(CH_3COO)_{2(aq)} + (NH_4)_2CO_{3(aq)} \rightarrow SrCO_3 + 2NH_4CH_3COO$$

$$Sr(CH_3COO)_{2(aq)} + (NH_4)_2SO_{4(aq)} \rightarrow SrSO_4 + 2NH_4CH_3COO$$

$$Sr(CH_3COO)_{2(aq)} + 2NH_4OH_{(aq)} \rightarrow Sr(OH)_2 + 2NH_4CH_3COO$$

In this investigation you will be reacting two compounds dissolved in water to produce two other compounds. The two reactants have a high solubility and if a precipitate forms, this means that one of the produced compounds has a low solubility. If a precipitate does not form, then the produced compounds formed both have a high solubility.

VISIONS

20. Use the periodic table on page 547 and the solubility table on page 548 of *Visions 2* to predict which reactions will form precipitates. Use the subscript (s) to indicate a precipitate and (aq) to indicate if the product is in solution.

PATHWAYS

If you have access to laboratory facilities, do Part A. If you do not have access to laboratory facilities, do Part B.

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Part A

Purpose

Practise using the solubility table, observe precipitation reactions, and use the results of precipitation reactions to identify unknown solutions.

Materials

The materials are given in Activity 7.1 on pages 248 and 249 of *Visions 2*.

Procedure

Follow Steps 2 to 6 in the Procedure section on page 249 of *Visions 2*. Omit the parts in Steps 4 and 5 on the effect of temperature on the formation of a precipitate.

Observations

21. Make and complete a chart similar to the one that follows. Record a check mark in the appropriate space if the two compounds reacted formed a precipitate.

	$Ca(CH_3COO)_{2(aq)}$	$Mg(CH_3COO)_{2(aq)}$	$Sr(CH_3COO)_{2(aq)}$
$(NH_4)_2CO_{3(aq)}$			
$(NH_4)_2SO_{4(aq)}$			
$NH_4OH_{(aq)}$			

Analysis and Interpretation

22. Answer questions 1 to 5 on pages 249 and 250 of *Visions 2*.

Check your answers by turning to the Appendix, Section 1: Activity 2.

End of Part A

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Part B

Purpose

Use the results of precipitation reactions to identify unknown solutions.

Materials

Data results are given in the Observations section.

Procedure

The chart given in the Observations section of this investigation contains the results obtained by an Alberta student when each of the solutions on the left was combined with each of the solutions across the top. Use these results to answer the questions in the Analysis and Interpretation section.

Observations

	$Ca(CH_3COO)_{2(aq)}$	$Mg(CH_3COO)_{2(aq)}$	$Sr(CH_3COO)_{2(aq)}$
$(NH_4)_2CO_{3(aq)}$	✓	✓	✓
$(NH_4)_2SO_{4(aq)}$	✓		✓
$NH_4OH_{(aq)}$	✓	✓	

Analysis and Interpretation

23. Answer questions 1 to 5 on pages 249 and 250 of *Visions* 2.

Check your answers by turning to the Appendix, Section 1: Activity 2.

End of Part B

In this activity you have learned how substances dissolve in water to form aqueous solutions and how colour or precipitation reactions can be a tool in qualitative analysis. In the next activity you will learn about some types of solutions and the reactions they undergo.

Activity 3: Classes of Solutions

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Investigation: What Type of Solutes Dissolve to Form Conducting Solutions?

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

Purpose

Determine what type of solutes dissolve to form conducting solutions.

Note: Some conductivity apparatus are very sensitive. Make sure to use distilled water when preparing solutions. You can buy distilled water at most drugstores. Keep the salt and sugar solutions for the next investigation.

Background Information

1. What type of compound is table salt $\left(NaCl_{(s)}\right)$? What type of compound is table sugar $\left(C_{12}H_{22}O_{11(s)}\right)$?

Materials

- table sugar
- table salt
- distilled water
- tap water
- conductivity apparatus
- 2 – 100 mL beakers
- test tubes or spot plates (dropper plates)

Procedure

Step 1: Make a chart for your observations. State yes if the solution conducts a current and no if it does not.

Step 2: Pour about 2 mL of distilled water into a test tube or put a few drops on the spot plate.

Step 3: Test the distilled water with the conductivity apparatus. If the bulb lights up, the solution conducts a current. Otherwise, it does not conduct a current.

Step 4: Dissolve about one teaspoon of table sugar into 50 mL of distilled water.

Step 5: Rinse the conductivity apparatus wires with distilled water before testing each new solution.

Step 6: Test the aqueous sugar solution with the conductivity apparatus in a test tube or on the spot plate.

Step 7: Dissolve about one teaspoon of table salt into 50 mL of distilled water.

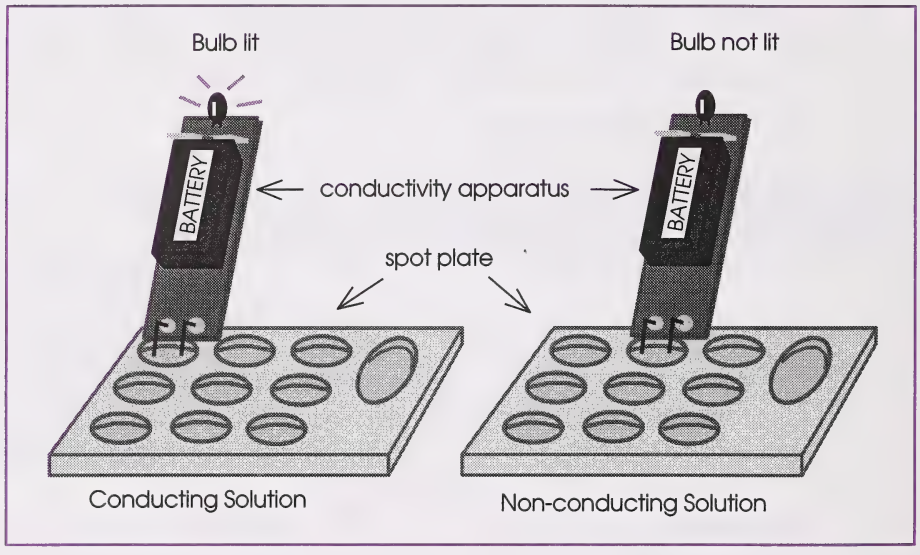
Step 8: Test the aqueous salt solution with the conductivity apparatus in a test tube or on the spot plate.

Step 9: Test a sample of tap water with the conductivity apparatus in a test tube or on the spot plate.

Step 10: Rinse the glassware, plastic containers, and other equipment used for solutions thoroughly after use.

Observations

2. Record your observations in your chart.



Analysis and Interpretation

3. You tested distilled water and tap water. Were your results identical? Explain.

4. What characteristics can you identify about aqueous solutions that conduct electricity?

electrolyte – a solute that dissolves to form a conductive solution

non-electrolyte – a solute that does not form a conducting solution when it dissolves

Check your answers by turning to the Appendix, Section 1: Activity 3.

Using a conductivity apparatus is one method to show that ions exist in a solution. Soluble ionic compounds like table salt dissolve and form ions. Because of this ability, this class of solute is called an **electrolyte**. Molecular compounds like sugar do not form conducting aqueous solutions; therefore, this class of solute is called a **non-electrolyte**.

VISIONS

To learn more about ions, read page 252 of *Visions 2* beginning with Figure 7.6.

5. What are the symbols of the ions in an aqueous table salt solution?

6. Describe two differences between the formulas for table salt and for the ions in an aqueous table salt solution.

7. List three solutions which contain electrolytes.

8. What types of solutes would make the light bulb of a conductivity apparatus glow faintly?

Check your answers by turning to the Appendix, Section 1: Activity 3.

Classifying solutions as containing electrolytes or non-electrolytes is not the only way that chemists categorize aqueous solutions. Another method is to classify them as acids or bases using the litmus test. The litmus test is one method of qualitative analysis that uses colour. There are many different **indicators** you can use, but red and blue litmus paper are the most common. Acids turn blue litmus red and bases turn red litmus blue. A substance which is neither an acid or a base is neutral and will not change the colour of blue or red litmus paper.

indicators – dyes that change colour depending on the acidity of the solution

Investigation: Acids, Bases, and What?

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

Purpose

Investigate a number of properties of various solutions.

Background Information

Note that you can either use the aqueous salt and sugar solutions from the previous investigation, or you can prepare new ones.

Materials

- aqueous salt solution
- aqueous sugar solution
- vinegar
- baking soda
- conductivity apparatus
- red and blue litmus paper
- distilled water
- test tubes or spot plates
- magnesium metal
- steel wool

Procedure

Step 1: You will test four solutions for conductivity, colour change of red and blue litmus paper, and reaction with magnesium. Make a chart to record the results of each test for the four solutions.

Step 2: Dissolve some baking soda in distilled water. The other substances are already in aqueous form unless you are making new sugar and salt solutions.

Step 3: Place a small amount of each solution in a test tube or on a spot plate.

Step 4: Test the conductivity of the four solutions. Test each solution with red litmus paper. Test each solution with blue litmus paper.

Step 5: Clean the piece of magnesium with steel wool until it is very shiny; then cut four small pieces about 2 mm or 3 mm long from the magnesium strip.

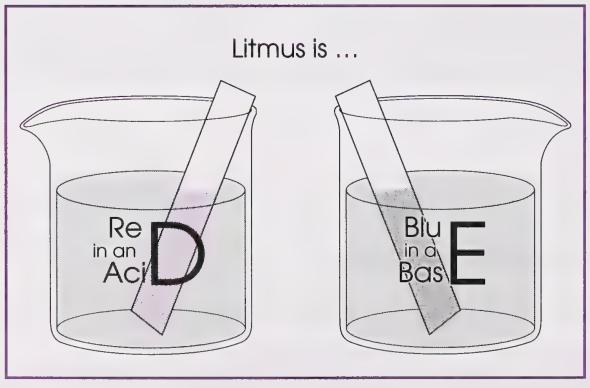
Step 6: Place a small piece of magnesium into each solution. Watch the solutions for a few minutes and see if a reaction happens with each solution.

Observations

9. Record your observations in your chart.

Analysis and Interpretation

The following relation should help you to remember the colour of litmus paper in acids and bases.



10. Classify the substances as an acid, a base, or neither.

11. What happens to the litmus papers when testing a neutral solution?

12. Is it possible to test for a neutral solution using only one colour of litmus paper? Explain your answer.

13. What types of compounds can form neutral solutions?

14. What properties are seen only in an acid?

Check your answers by turning to the Appendix, Section 1: Activity 3.



To discover more properties of acids and bases and to see some kinds of reactions they undergo, view the video entitled *Acids and Bases*, Magic Lantern Communications Ltd., ACCESS Network. This video is available from Learning Resources Distributing Centre. The first half of the video is the part that you need to focus on. Before you view the video, read over the following questions and be prepared to find the answers.

15. Make and complete a chart like the following using the base example and the acid example. Note: The bullets indicate the number of items each category should have.

	Name	Some of Its Uses	General Properties
Base	•	• •	• • • •
Acid	•	• •	• • • •

16. For the three reactions demonstrated, write down the name of the reactants and record the observations.

Reaction	Reactants	Observations
1		
2		
3		

17. What caused the bubbles in the reaction between the acetic acid and the sodium bicarbonate?

18. What process occurs when you take an antacid to help your upset stomach?

Check your answers by turning to the Appendix, Section 1: Activity 3.

neutralization reaction – chemical change involving an acid and base forming an ionic compound and water

Now that you have seen some examples of **neutralization reactions**, you should review how to write a neutralization reaction. You may recall from Science 10 that an acid-base reaction is a double replacement reaction. When you predict the products of a double replacement reaction, the positive ions switch partners with the negative ions. For example, in the following reaction, the two compounds react to form two different compounds.

$$\underset{\text{acid}}{HNO_{3(aq)}} + \underset{\text{base}}{KOH_{(aq)}} \rightarrow \underset{\text{salt}}{KNO_{3(aq)}} + \underset{\text{water}}{HOH_{(l)}}$$

Note that the H^+ and K^+ ions are changing partners so that, after the reaction, they are paired up with different ions. (Water can also be written as $H_2O_{(l)}$.)

When nitric acid neutralizes potassium hydroxide, two new compounds are formed – water and an ionic compound. Generally, the compound is soluble. However, you should check the solubility table to make sure. When you are predicting the products of a neutralization reaction, it is usually best to do the following:

Step 1: Write the ions formed when the reactants dissolve in water.

Step 2: Partner the ions to form a compound using the simplest ratio of positive charges to negative charges.

Step 3: Write the states of the products using common knowledge (water is a liquid) and a solubility table (for the ionic compound).

Step 4: Balance the equation.

In the example that follows, the steps are described fully to remind you of how this is done.

Example:

What reaction takes place when solid calcium hydroxide reacts with nitric acid solution?

The solution is as follows:

Step 1: $Ca(OH)_{2(s)} + HNO_{3(aq)} \rightarrow$

$Ca(OH)_{2(s)}$ will produce Ca^{2+} ions and OH^- ions. $HNO_{3(aq)}$ will produce H^+ ions and NO_3^- ions. Ca^{2+} ions will pair up with NO_3^- ions and OH^- ions with H^+ ions.

Step 2: $Ca(OH)_{2(s)} + HNO_{3(aq)} \rightarrow Ca(NO_3)_2 + HOH$

Step 3: $Ca(OH)_{2(s)} + HNO_{3(aq)} \rightarrow Ca(NO_3)_{2(aq)} + HOH_{(l)}$

Calcium nitrate is soluble according to the solubility table, and water is a liquid.

Step 4: $Ca(OH)_{2(s)} + 2HNO_{3(aq)} \rightarrow Ca(NO_3)_{2(aq)} + 2HOH_{(l)}$

Note: When water is written as HOH, the equation is easier to balance.

19. Write the products and a balanced equation for each of the following reactions.

a. $HF_{(aq)} + NaOH_{(aq)}$

b. $H_2SO_{4(aq)} + KOH_{(aq)}$

c. $CH_3COOH_{(aq)} + NaOH_{(aq)}$

d. Barium hydroxide is neutralized by nitric acid.

Check your answers by turning to the Appendix, Section 1: Activity 3.

VISIONS

Now that you have tried some of the qualitative tests used to define three classes of solutions, read pages 252 to 254 of your textbook to learn how the properties of acids and bases were explained by Arrhenius.

20. Make and complete a chart like the one that follows by writing the class of solution (acid, base, neutral ionic, or neutral molecular) next to the property. A particular property may be shown by more than one class of solution.

Property	Class of Solution
conductive solution	
tastes sour	
reacts with metals to form hydrogen gas	
causes a change in litmus paper	
participates in neutralization reactions	

21. According to Arrhenius, what is the formula of the ion responsible for the properties of an acid?

22. What is the ion responsible for the properties of a base?

23. What is a *neutralization reaction*?

Check your answers by turning to the Appendix, Section 1: Activity 3.

Acidic properties can be completely destroyed if you react an acid with a base. In the next investigation you will be classifying solutions and then neutralizing an acid with a base.

Investigation: Classifying and Neutralizing Acids and Bases

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

VISIONS

PATHWAYS

If you have access to laboratory facilities, do Pathway A. If you do not have access to laboratory facilities, do Pathway B.

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Pathway A involves performing Activity 7.2, on pages 254 to 257 of *Visions 2*. Pathway B involves an alternate investigation.

Pathway A

Follow the directions of Activity 7.2 on pages 254 to 257 of *Visions 2*. Also, take note of the following instructions:





- When reacting magnesium, make sure you have polished the metal with steel wool. Cut the magnesium strip into pieces about 2 mm or 3 mm long. You may need larger pieces if you are performing the hydrogen and oxygen test. Do not perform these tests without supervision.
- Review Skill 9 on pages 535 and 536 of *Visions* 2. Follow the procedure carefully when performing the hydrogen and oxygen test.
- Rinse glassware, plastic containers, and other equipment used for solutions thoroughly after use.

Purpose

Classify various solutions as acidic, basic, or neutral, and neutralize an acid with a base.

Part A

Background Information

24. List the solutions to be tested and predict from the formulas whether each is an acid, a base, or a neutral solution.

Materials

Review the list of materials on page 255 of your textbook.

Procedure

Follow Steps 2 to 6 in the Procedure section on page 255 of your textbook. Do Step 6 before you do Steps 2 to 5 since the presence of the magnesium metal may affect the colour change or conductivity. Make a chart to record your observations.

Observations

25. Record your observations in the chart you made.

Analysis and Interpretation

26. Classify each solution as being an acid, a base, or a neutral solution.

27. Do questions 1 to 5 in the Analysis and Interpretation section on page 256 of *Visions* 2.

Check your answers by turning to the Appendix, Section 1: Activity 3.

End of Part A

Part B

Materials

Review the list of materials on page 256 of your textbook.

Procedure

- Make a chart to record your observations of the number of drops of base and acid required in each trial.
- Follow the Procedure section on page 256 of your textbook.
- Omit Step 5.

Observations

28. Record your observations in your chart.

29. After the hydrochloric acid was neutralized, ten more drops of base were added. To neutralize this additional base, an average of ten drops of additional hydrochloric acid were added. What does this indicate about the volume of hydrochloric acid required to neutralize a given volume of sodium hydroxide?

Analysis and Interpretation

30. Do questions 1 to 3 in the Analysis and Interpretation section on pages 256 and 257 of *Visions 2*.

Check your answers by turning to the Appendix, Section 1: Activity 3.

End of Part B

End of Pathway A

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

Pathway B

Follow the directions of this investigation carefully. Also, take note of the following instructions:

- About 5 mL of $HCl_{(aq)}$ and 5 mL of NaOH are required for Part A of this investigation. Keep the remaining amounts of $HCl_{(aq)}$ and $NaOH_{(aq)}$ for Part B.



- When reacting magnesium metal, make sure you polish the metal with steel wool.
- Cut the magnesium into pieces about 2 mm or 3 mm long. Keep the pieces small so there is not too great a reaction.
- Rinse glassware, plastic containers, and other equipment used for solutions thoroughly after use.

Purpose

Classify various solutions as acidic, basic, or neutral, and neutralize an acid with a base.

Part A

Background Information

31. List the solutions given and predict from the formulas whether each is an acid, a base, or a neutral solution.

Materials

- 0.10 mol/L $HCl_{(aq)}$
- 0.10 mol/L $NaOH_{(aq)}$
- household ammonia cleaner, $NH_{3(aq)}$
- distilled water, $H_2O_{(l)}$
- vinegar, $CH_3COOH_{(aq)}$
- baking soda, $NaHCO_{3(aq)}$
- laundry soap, contains SO_3^- ions
- sugar, $C_{12}H_{22}O_{11(aq)}$
- table salt, $NaCl_{(aq)}$
- red and blue litmus paper
- spot plate
- 3 small test tubes
- eye dropper
- magnesium metal, $Mg_{(s)}$
- conductivity apparatus
- steel wool

Procedure

Step 1: Make a chart to record your observations.

Step 2: Place a small amount of $HCl_{(aq)}$ on the spot plate or in a test tube and test it with the conductivity apparatus.

Step 3: Add about 1 mL of $HCl_{(aq)}$ to a test tube and test it with red and blue litmus paper.

Step 4: Add about 1 mL of $HCl_{(aq)}$ to a test tube. Add a small piece of magnesium metal to the solution and observe any reaction.

Step 5: Repeat Steps 1 to 3 with each of the other solutions. Rinse the test tubes with distilled water before testing a new solution.

Observations

32. Record your observations in your chart.

Analysis and Interpretation

33. Classify each substance.

34. What gas do you think is being released from the solutions that reacted with the magnesium metal?

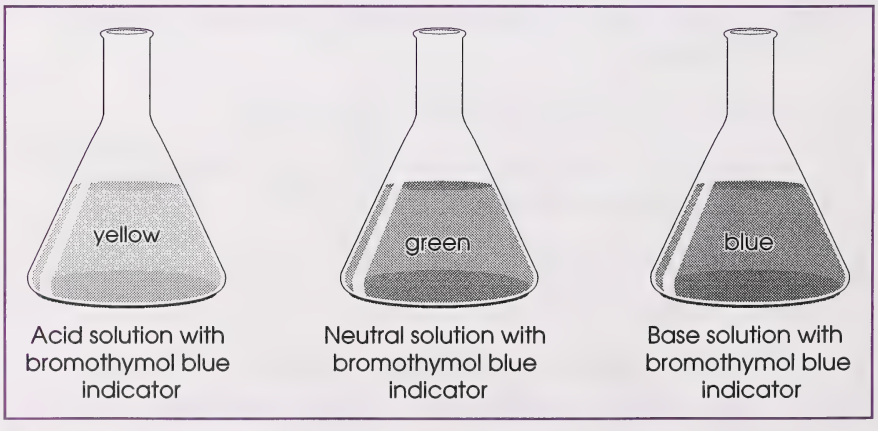
Check your answers by turning to the Appendix, Section 1: Activity 3.

End of Part A

Part B

Background Information

Basic (or alkaline) properties can be neutralized by acids. You can tell when this has happened by using an indicator. In this part of the investigation, you will be neutralizing an acidic solution with a basic solution. The indicator, bromothymol blue, is a dye that will show you when neutralization has occurred because the solution will turn green. If the solution is acidic, then the solution with bromothymol indicator is yellow. If the solution is alkaline, the solution will be blue.



You may have some $HCl_{(aq)}$ and $NaOH_{(aq)}$ leftover after completing this part of the investigation. Before disposing of it, you can neutralize both the acid and the base by adding equal amounts of each together.

Materials

- 0.10 mol/L $HCl_{(aq)}$
- 0.10 mol/L $NaOH_{(aq)}$
- bromothymol blue indicator
- small test tube
- eye dropper

Procedure

Step 1: Make a chart to record your observations.

Step 2: Add 20 drops (1 mL) of hydrochloric acid to the test tube.

Step 3: Add two to three drops of bromothymol blue to the test tube and swirl.

Step 4: Add the sodium hydroxide drop by drop into the test tube until a green colour appears. Swirl the contents with each drop added.

Step 5: Record the number of drops of base needed to achieve a green colour.

Step 6: Repeat Steps 1 to 4 to double-check your results.

Observations

35. Record your observations in your chart.

Analysis and Interpretation

36. Write a balanced equation for the neutralization reaction.

37. What is the formula of the ion that caused the indicator to turn green?

38. What type of compound is a salt?

Check your answers by turning to the Appendix, Section 1: Activity 3.

End of Part B

End of Pathway B

Part of your experiences in science need to include planning and designing appropriate investigations. The following investigation allows you to design, perform, and evaluate an investigation.

Investigation: A Homemade Indicator Lab

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

Science Skills

- ☑ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

39. You are given a recipe for a homemade indicator. Devise a way to classify four common household solutions as acids or bases. Write a complete report on your investigation. Include all the appropriate parts. In the Analysis and Interpretation section, classify the four solutions you choose and evaluate how well the indicator performed. Discuss why it could or could not be used in a scientific laboratory.



A Purple Cabbage Indicator

- Grate $\frac{1}{4}$ of a fresh purple cabbage. You could also chop it in your food processor or chop it finely using a knife.
- Place the grated purple cabbage into unsalted boiling water, and boil for 10 min.
- Collect the boiled solution using a strainer to remove the pieces of boiled purple cabbage.

Check your answers by turning to the Appendix, Section 1: Activity 3.

In this activity you learned two ways to classify solutions. Solutions can be classified on the basis of their conductivity or they can be classified on the basis of whether they are acidic, basic, or neutral. Acids and bases have the ability to react and destroy each other's properties.

In the next Section you will learn about quantitative descriptions of solutions and how to prepare solutions.

Follow-up Activities

If you had difficulties understanding the concepts in these activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

VISIONS

1. Make and complete the following chart identifying five unknown solutions using Table 5.2 in Activity 2, the solubility table on page 548 of *Visions 2*, and your knowledge of solutions.

Solution	Qualitative Test	Observation	Classification or Identity
A	colour of solution	purple	
B	mixed with $NaCH_3COOH_{(aq)}$	white precipitate forms	
C	conductivity meter	light glows	
D	red litmus blue litmus	turns blue stays blue	
E	magnesium	bubbles	

VISIONS

2. In this section you also learned that you could use a solubility table to predict from the equation if any of the resulting products will form precipitates. Write a balanced equation for each of the following reactants; then, classify the reactions as precipitation reactions or neutralization reactions. Refer to the solubility table on page 548 of *Visions 2* to help you with this classification.

   a. $AgNO_{3(aq)}$ is mixed with $NaCl_{(aq)}$.

   b. $NaOH_{(aq)}$ is mixed with $HBr_{(aq)}$.

   c. Solutions of calcium chloride and potassium sulphate are mixed.

   d. Solutions of potassium hydroxide and nitric acid are mixed.

3. In the following chart, classify each of the components of the three solutions as either a solute or a solvent.

Solution	Component	Amount	Solute or Solvent?
Tooth Filling	mercury	50%	
	silver	35%	
	tin	15%	
Air	argon	0.93%	
	carbon dioxide	0.03%	
	oxygen	20.9%	
	nitrogen	78.1%	
	others	0.04%	
Steel	tungsten	8%	
	nickel	14%	
	iron	51%	
	chromium	24%	
	copper	3%	

4. If you are given three unlabelled solutions and you are told that they are either $HNO_{3(aq)}$, $NaOH_{(aq)}$, or $NaCl_{(aq)}$, describe how you can tell which solution is which.

5. An unknown green solution is mixed with sodium chloride solution.

   a. According to the colour of the unknown solution, what ions can it contain? Use Table 5.2 in Activity 2.

   b. If the solution forms a precipitate with sodium chloride solution, what ion is present? Use the solubility table on page 548 of *Visions* 2.

6. Explain why you cannot see any of the changes happening in a saturated solution.

7. List three substances found in your home that are acidic and three substances that are basic.

8. a. What two types of compounds dissolve well in water?

   b. What property of water allows it to dissolve these compounds?

Check your answers by turning to the Appendix, Section 1: Extra Help.

Enrichment

Do any two of the next three questions.

1. Using toothpicks and jujubes, create a model that shows how a water molecule can enter an ionic crystal and cause it to dissolve.

2. Perform the following investigation over the next two weeks.

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Investigation: How Dynamic Can a Solution Be?

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

Purpose

Observe the changes that happen in a saturated solution over an extended period of time.

Materials

- baking soda (or use pickling salt, rock salt, water softening salt, or table salt)
- tap water
- small transparent jar that can be sealed (about 250 mL)

Procedure

Step 1: Fill the jar about three-quarters full with tap water at room temperature.

Step 2: Add one tablespoon of the compound. Close the lid tightly and invert several times.

Step 3: Keep adding the compound and mixing until some of the compound remains in solid form on the bottom.

Step 4: For the next fourteen days, invert the jar several times each day.

Step 5: Make a chart to record your observations.

Step 6: Record the appearance of the crystals and the settling-out time.

Observations

a. Record your observations over the next fourteen days in your chart.

Analysis and Interpretation

b. What happens to the settling-out time over the fourteen-day period?

c. Does the solution in the jar seem to be the same over the fourteen days? Include some observations to explain your answer.

d. How does this experiment verify the concept of dynamic equilibrium?

3. Sulphuric acid $\left(H_2SO_{4(l)}\right)$ is the acid that is most commonly used by industry. Explore its production and uses. Why is sulphuric acid the acid of choice? Summarize your findings in a one- to two-page report.

Check your answers by turning to the Appendix, Section 1: Enrichment.

Conclusion

Aqueous solutions are homogeneous mixtures that can be classified in several ways depending on the solute dissolved. You can identify the contents of solutions using qualitative tests such as colour, electrical conductivity, or by a process of elimination precipitation reactions. You can also describe solutions as acidic, basic, neutral ionic, or neutral molecular. In the next section, you will learn how to prepare solutions to a given concentration.

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 1.

Section

2 Concentration – There's Exactly How Much?



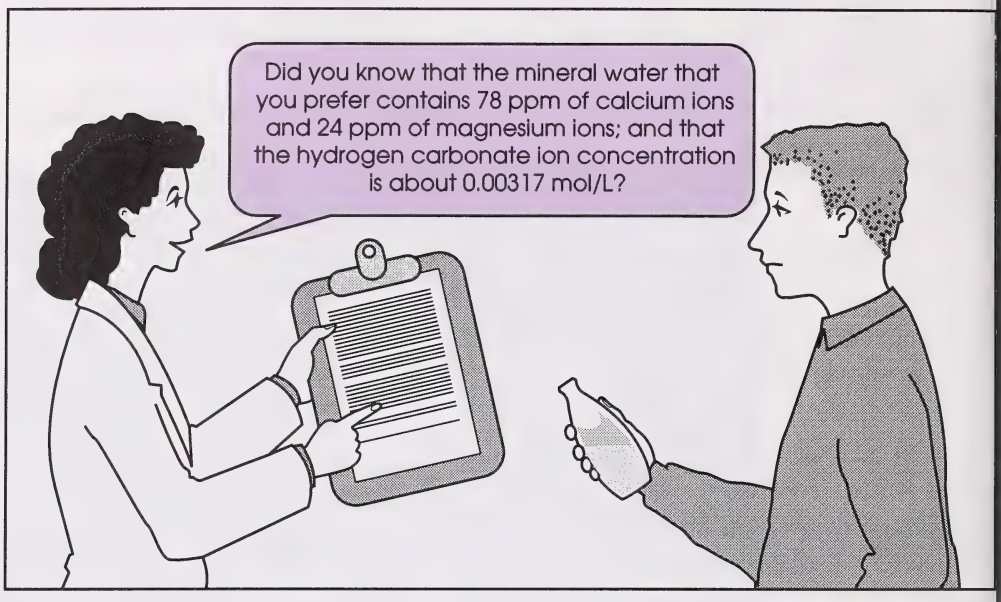
WESTFILE INC.

Imagine the feeling you experience when you drive down a stretch of road in a dense fog. Even though you may be travelling slowly, you may feel that you are racing down a dangerous stretch of road. But have you ever stopped to think that you are also travelling through a solution?

Solutions, like fog, can be described based upon the amount of solute. Fog can be so thick that your visibility is nearly zero; it can also be so thin that the visibility on the road is two kilometres. Scientists use a variety of ways to describe aqueous solutions.

In this section you will examine different ways that scientists describe solution concentration, how to prepare a solution, as well as how to assess the risks and benefits of chemical use in society.

Activity 1: Consumers and Scientists



Do you drink mineral water? Mineral water is not pure water. It may contain different minerals as described in the previous illustration. Are you familiar with the units used?

Sometimes the way you say things depends on what you want to communicate. When you need to know how much of a solute is present, you can use either quantitative or qualitative descriptions.

1. How do you think a scientist would describe a very weak cup of coffee qualitatively?

Check your answers by turning to the Appendix, Section 2: Activity 1.

However, if a scientist was to describe the coffee quantitatively, then the description needed would include amounts of the solute and amounts of the solvent. Concentration is the term that describes how concentrated or diluted a solution is. To describe the concentration of an aqueous solution, you would tell how much solute has been dissolved in a certain amount of solvent.

For example, if you were to describe the concentration of an aqueous sugar solution, then you would use values that tell how much sucrose has been dissolved in a volume of water.

VISIONS

To study how scientists describe concentration, read pages 260 to 263 and page 266 of *Visions* 2.

2. In a chart, list the five methods used to describe concentration. Make a chart like the following. The textbook states four methods on page 260 but shows five methods on page 270. Percent by mass and percent by volume are considered to be two separate methods.

Method	Units	Used to Express	Example

3. If you need to describe the concentration of dye present in a swimming pool from one drop of food colouring, what method of describing concentration can you use?

Review the practice problems on page 261 involving percent by volume and on page 266 involving parts per million (ppm).

4. Do questions 1, 3, and 4 on page 262 of *Visions* 2.

5. Do questions 1, 2, and 4 on page 266 of *Visions* 2.

Check your answers by turning to the Appendix, Section 2: Activity 1.

Although scientists use different ways to communicate concentration, the method of choice in a laboratory is using units of mol/L. This is read as moles of solute per litre of solution. Moles of solute gives the amount of solute dissolved. Concentration is the amount of solute dissolved in a solvent (such as water) per one litre of solution. It is the SI method of describing concentration.

VISIONS

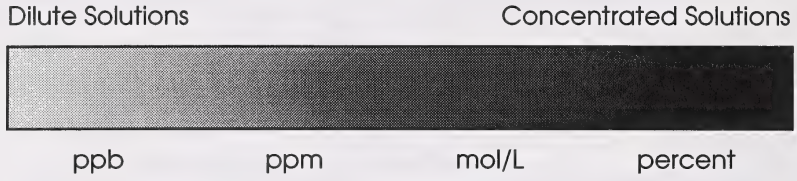
To find out how to calculate the concentration of a solution in moles per litre, read the top half of page 267 of *Visions* 2.

6. What is the concentration of a solution that contains 3.50 mol of dissolved sodium phosphate in 2.00 L of water?

7. What is the concentration of a calcium chloride solution if 0.700 mol of solute is dissolved in 1.5 L of water?

Check your answers by turning to the Appendix, Section 2: Activity 1.

You can get a rough estimate of the concentration of a solution if you look at the kind of unit used. For example, if the unit of concentration is in parts per billion, this solution is very dilute compared to a solution that is described in terms of percent by mass. The following figure shows how a glance at the unit gives you an idea of how concentrated the solution is.

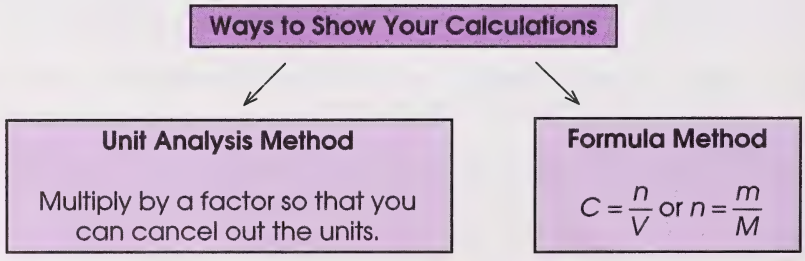


8. Which of the following measurements would alarm you the most if you read it on an analysis of your drinking water? Explain.

   Concentration of lead ions = 1.3 ppm
   Concentration of pesticides = 1.0 mol/L

Check your answers by turning to the Appendix, Section 2: Activity 1.

The way that you do calculations and show your work may be similar or different to the method used in your textbook. The textbook uses a method called unit analysis, which does not depend on memorized formulas. You need to learn this method so you can check your units even if you do prefer to use formulas to do calculations. The Appendix will show the answers in both ways. The two ways that you can show your work are shown in the following diagram:



Note: The unit analysis method is used in your textbook.

Unit Analysis Method

By using the unit analysis method, you can do all conversions and calculations without having to memorize formulas or having to manipulate a formula. The unit analysis method uses two main ideas. They are as follows:

- The factor you are multiplying by is a ratio that means 1 (or, in mathematical terms, is equal to 1 or = 1).
- The factor you are multiplying by is set up so that the units cancel to give you the units you need.

For example, you wanted to change 60.0 mL into units of litres using unit analysis. You know that 1 L = 1000 mL. The factor is either the ratio $\frac{1\text{ L}}{1000\text{ mL}}$ or $\frac{1000\text{ mL}}{1\text{ L}}$.

Now, you need to think about the units you are starting with and the units that you need. If you let the conversion factor be represented by CF, this can be thought of as follows:

60.0 mL × CF = ___ L (CF is one of the factors.)

9. Which factor should you multiply by so the mL units will cancel out to leave you an answer with the units of L?

Check your answers by turning to the Appendix, Section 2: Activity 1.

The factor is chosen so that the units cancel to give litres.

$$60.0\cancel{\text{mL}} \times \frac{1\text{ L}}{1000\cancel{\text{mL}}} = 0.0600\text{ L}$$

VISIONS

Notice that the significant digits in 60.0 mL remains the same in 0.0600 L. (Remember: The zeros left of the 6 are not significant in this case.) The numbers 1 and 1000 are exact numbers and therefore have no effect on the number of significant digits. You may want to review the rules for significant digits on pages 544 and 545 of *Visions 2*.

Finding Amounts (moles)

If you are going to describe solutions quantitatively, then you must use the units in chemistry that describes amount. In the lab, you use a particular unit to measure how much of a substance there is.

10. What is the unit used in the lab to measure the mass of a substance?

Check your answers by turning to the Appendix, Section 2: Activity 1.

molar mass – the number of grams of a substance needed to make one mole; symbolized by *M*

To change grams (the unit describing mass of a substance) to moles use the **molar mass** as the factor. Here is an example of changing a mass unit to moles.

What is the number of moles present in 3.60 g of $Ca_3(PO_4)_{2(s)}$?

If you think of the question as a multiplication problem, it will look as follows:

$$3.60\ g \times CF = \_\_\_\ mol$$

The conversion factor (CF) in this case is the molar mass. Recall from Science 10 that molar mass is found by adding the atomic masses of the atoms in the formula unit. In the case of calcium phosphate, you need to know the number of moles of each of the atoms in the formula unit.

VISIONS

This is done by finding the number of moles of each atom from the chemical formula and the atomic mass from the mass of each element as given on page 547 of *Visions* 2. You may recall calculating atomic mass for a given compound in Science 10. This is illustrated in the following chart.

Atomic Symbol	Atomic Mass (g/mol)	Number of Moles
Ca	40.08	3
P	30.97	2
O	16.00	8

To find the molar mass, total the atomic masses of all the elements. The calculation of this is shown as follows:

$$\begin{aligned}\text{molar mass} &= \left[(3\times 40.08)+(2\times 30.97)+(8\times 16.00)\right]\text{g/mol}\\ &= 310.18\text{ g/mol}\end{aligned}$$

To convert 3.60 g to the number of moles, would you multiply by $\frac{310.18\text{ g}}{1\text{ mol}}$ or $\frac{1\text{ mol}}{310.18\text{ g}}$?

Since you want the remaining unit to be moles, the calculation is as follows:

$$3.60\text{ g}\times\frac{1\text{ mol}}{310.18\text{ g}} = 0.0116\text{ mol}\ \ (3\text{ significant digits})$$

11. Calculate the number of moles present in each of the following.

    a. 2.73 g of H_2SO_4 b. 0.016 g of NaOH c. 15.0 g of $(NH_4)_2SO_4$

12. Calculate the number of grams present in each of the following.

    a. 0.317 mol of $(NH_4)_2CO_3$ b. 0.086 mol of $Sr(CH_3COO)_2$

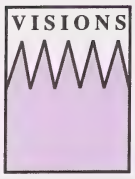
VISIONS

Before you can use the unit analysis method, you need to know the measurements and their units. Reread pages 266 and 267 of *Visions 2*, and do the following question.

13. Complete the following chart by adding in the missing unit or measurement.

Measurement	Unit
volume	
	mol/L
amount	

Check your answers by turning to the Appendix, Section 2: Activity 1.



Read over the three example problems on pages 267 to 269 of *Visions 2*. The unit analysis method is used in these examples in the textbook.

If you understand this method, you can go on to question 14. Question 14 follows the examples which use the formula method.

The following pages illustrate the formula method. You may wish to use this method when doing questions in stoichiometry. However, you need to understand unit analysis so you can check your units.

Formula Method

The formula method can be a longer method of showing your calculations for concentration and moles. Two equations are involved, each of which can be manipulated three different ways.

The formula $C = \frac{n}{V}$ is used when you have a given volume of a solution. This formula can be rearranged as $n = CV$ or $V = \frac{n}{C}$. The formula $n = \frac{m}{M}$ is used when you have a given mass of solute. This formula can also be rearranged as $m = Mn$ or $M = \frac{m}{n}$.

Table 5.3 describes the measurement and the unit of each symbol used in the previous two formulas.

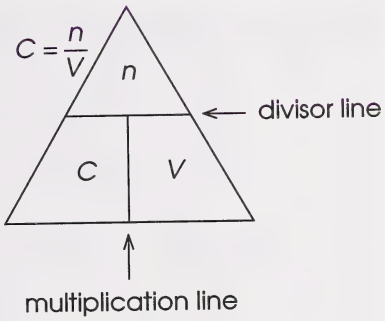
TABLE 5.3 UNITS AND SYMBOLS FOR MEASUREMENTS INVOLVING CONCENTRATIONS AND MOLES

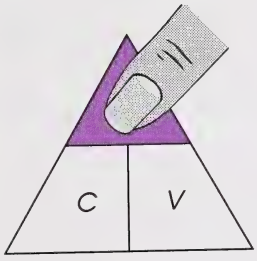
Measurement	Symbol	Unit
concentration	C	mol/L
moles (amount)	n	mol
volume	V	L
mass	m	g
molar mass	M	g/mol

Once you know the formulas and what they mean, then all the problems can be written down by using the following steps.

Step 1: List the variables (with base units) and symbols.
Step 2: Write the equation that you need to use to solve the problem.
Step 3: Solve the equation for the variable needed.
Step 4: Substitute the values and calculate the answer.

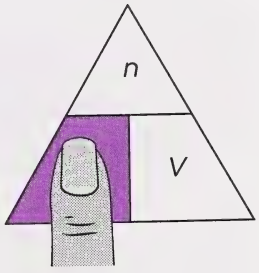
The following diagrams may be of use when you rearrange the formulas $C = \frac{n}{V}$ and $n = \frac{m}{M}$. You might use these diagrams as a check after you have rearranged the formula by solving for the variable you want. The formula $C = \frac{n}{V}$ is shown in diagram form.





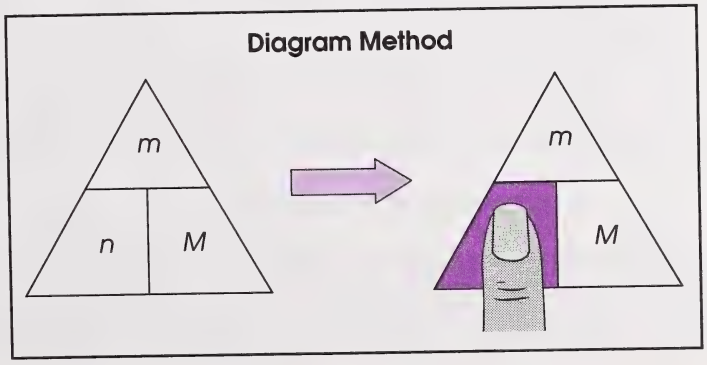
This type of diagram may be easier for you to use to solve problems. For example, if moles (n) is the unknown you are solving for, covering n (with your thumb or some object) shows you how to solve the problem – multiply $C \times V$.

In another example, if concentration (C) is the unknown, the problem is solved by dividing n by V. Whether or not you use this method of solving problems is up to you.



The relationship $C = \frac{n}{V}$ uses the moles of solute in the calculation. In the lab, however, the mass of solute is measured on a balance. In some of the calculations you will need to change the moles of solute into mass, or vice versa.

The formula $n = \frac{m}{M}$ can be shown in a similar diagram as follows.



Example: Changing Mass to Moles

How many moles of calcium hydroxide are present in 4.8 g of $Ca(OH)_{2(s)}$?

The data is as follows:

$m = 4.8\ g$

$M = (1 \times 40.08) + (2 \times 16.00) + (2 \times 1.01)$

$= 74.10\ g/mol$

$n = ?$

The solution is as follows:

$$n = \frac{m}{M}$$

$$= \frac{4.8\ g}{74.10\ g/mol}$$

$= 0.065$ mol (2 significant digits)

The formula method is similar when you are doing calculations involving the preparation of solutions.

Example: Calculating the Number of Moles in a Solution

How much solute dissolved in 135 mL of 0.300 mol/L $NaCl_{(aq)}$?

The data is as follows:

$C = 0.300\ mol/L$

$V = 135\ mL$

$= 0.135\ L$

$n = ?$

The solution is as follows:

The formula you should use is $C = \frac{n}{V}$.

However, you need to find n. You can use the diagram method described previously, or you can solve for n as follows:

$$V \times C = \frac{n}{V} \times V$$

$$V \times C = n$$

$$n = CV$$

$= 0.300\ mol/L \times 0.135\ L$

$= 0.0405$ mol (3 significant digits)

The solution becomes a little more complex when a combination of both formulas is needed to solve a problem. You may encounter calculations like this when you need to determine the mass of solute needed for dissolving. Follow the next example.

Example: Calculating the Mass Needed to Make a Certain Concentration

What mass of sodium hydroxide do you need to make 100 mL of a 0.500 mol/L $NaOH_{(aq)}$ solution?

The data is as follows:

$C = 0.500$ mol/L
$V = 100$ mL
$= 0.100$ L
$n = ?$
$M = (22.99 + 16.00 + 1.01)$
$= 40.00$ g/mol
$m = ?$

The solution is as follows:

Based on the list of variables, the number of moles must be calculated first using the concentration and the volume. When you know the number of moles, then the mass can be found. So, the first formula you should use is $C = \frac{n}{V}$.

Rearrange the formula to solve for n (number of moles).

$$n = CV$$
$$= 0.500 \text{ mol/L} \times 0.100 \text{ L}$$
$$= 0.0500 \text{ mol}$$

Now, the formula you should use is $n = \frac{m}{M}$. Rearrange the formula to solve for m (mass in grams) by multiplying each side of the equation by M.

$$m = nM$$
$$= 0.0500 \text{ mol} \times 40.00 \text{ g/mol}$$
$$= 2.00 \text{ g} \quad (3 \text{ significant digits})$$

Note: When using a calculator for these problems, keep all the digits in the calculator after finding the number of moles (n); then use the second formula to find the concentration (C). Since this is the final step, round the answer to the appropriate number of significant digits. Use brackets and or calculator memory to maintain all the digits until the last step.

VISIONS

14. Now that you have followed a couple of examples using the unit analysis method and the formula method, do questions 2, 4, 6, 8, 12, and 13 on pages 269 and 270 of *Visions* 2. Use the unit analysis method to do the questions.

Check your answers by turning to the Appendix, Section 2: Activity 1.

In this activity you have learned how solutions are described quantitatively. In the next activity, you will learn how to make a solution.

Activity 2: Preparing Solutions



What kind of a chef would you make? Are you a good technician, able to follow complicated recipes, or are you a cook with an artistic flair, capable of turning the most boring meals into exciting creations?

1. Make a list of good reasons for following a recipe precisely compared to adjusting and personalizing a recipe. Set up a chart like the following.

Good Reasons for Following a Recipe Exactly	Good Reasons for Changing a Recipe Here and There

Check your answers by turning to the Appendix, Section 2: Activity 2.

When you are preparing chemicals, you may need to adjust the amounts of the reactants in an exact fashion. Solutions need to be precise; thus, in this activity, you will be focusing on your practical skills. Now that you have learned how to do the necessary calculations, you will learn to make the actual solutions.

Aqueous solutions are prepared in two ways. The following table shows the methods that are used.

TABLE 5.4 PREPARING AQUEOUS SOLUTIONS

From a Pure Solid	From a Concentrated Liquid
• process called dissolution • concentration $= \frac{\text{moles}}{\text{litres}}$	• process called dilution • $C_1V_1 = C_2V_2$

Although it may not be obvious right away, you are probably more familiar with dilution than dissolution.

2. List three solutions in your home that you water down before use.

Does the amount of chemical in the concentrated liquid change during the dilution process? Take the watering down of plant fertilizer as a dilution of an aqueous solution.

3. When you add three drops of blue liquid fertilizer to a 1.0 L watering can, does the amount of fertilizer change?

Check your answers by turning to the Appendix, Section 2: Activity 2.

VISIONS

The idea that the amount of chemical does not change even though water has been added is the basic concept behind the formula $C_1V_1 = C_2V_2$. To find out how this dilution formula was put together, read pages 270 and 271 of *Visions* 2.

4. According to the example of the magnesium sulphate dilution, which solution is most concentrated, C_1 or C_2?

5. Which volume is always larger, V_1 or V_2?

6. How do you determine the amount of water you need to dilute V_1 to V_2?

7. Practise the dilution calculations by doing practice problems 1 to 4 on pages 271 and 272 of *Visions* 2. Use the method shown on page 271 of your textbook.

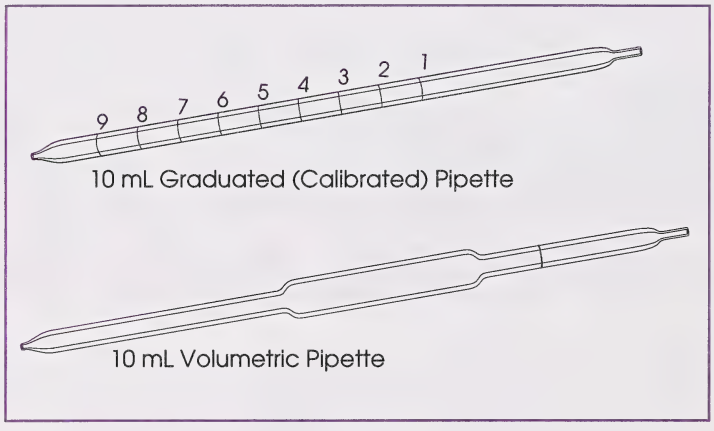
VISIONS

Before you do the investigation that practises the techniques involved in solution preparation, read over Skill 11 and Skill 12 in Appendix A on pages 536 and 537 of *Visions 2*.

8. What is the name of the container that the solution is made in?
9. When making a solution from a solid, why do you dissolve the solid in a beaker first?
10. Why do you rinse the beaker three times with distilled water into the volumetric flask or graduated cylinder?

Check your answers by turning to the Appendix, Section 2: Activity 2.

In the next investigation, which involves Activity 7.3 of your textbook, you will be using a graduated pipette to transfer a quantity of a more concentrated solution to a volumetric flask or graduated cylinder. The textbook uses the term calibrated instead of graduated. The following diagram illustrates two types of pipettes, a graduated pipette and a volumetric pipette.



The 10 mL graduated pipette which you are going to use can be used to transfer any amount of a liquid between 0 mL and 10 mL with an accuracy of ±0.1 mL. The volumetric pipette is used to transfer a more precise amount of a liquid – in this case 10 mL accurate to ±0.04 mL.

Caution

You are going to practise using the 10 mL graduated pipette with tap water. If you are in a classroom, check with your teacher regarding a pipette and bulb. If you are working on your own and have a loan kit, find the 10 mL graduated pipette and squeeze bulb in your loan kit. Use the squeeze bulb to draw solution into the pipette. Never use your mouth to draw liquids into the pipette.

Practise using the graduated pipette with tap water by following these steps.

Step 1: Set up two 100 mL beakers – one with about 50 mL of tap water, and the other empty as a waste beaker.

Step 2: Set up your graduated cylinder into which you will place the measured amount of solution.

Step 3: The pipette is held between the thumb and fingers near the top. Keep your index finger free.

Step 4: Place the pipette in the sample solution with the tip resting on the bottom.

Step 5: Squeeze the bulb completely with the palm of your other hand and place the bulb firmly on to the end of the pipette.

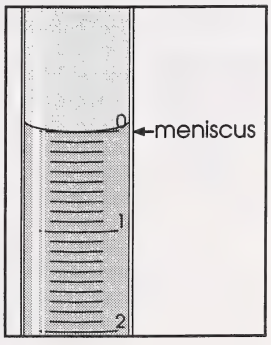
Step 6: Slowly release your grip until the solution has risen above the calibration line.

Step 7: Remove the bulb and quickly place your index finger over the top. Be careful not to tip your solution container over.

Step 8: If you do not have enough liquid in the pipette you will have to repeat Steps 5 to 7.

Step 9: Lift the pipette from the solution container and wipe all the liquid from the outside using a paper towel.

Step 10: With the tip of the pipette touching the inside of the waste beaker, carefully roll your index finger or rotate the pipette between your thumb and your fingers, allowing the liquid level to drop until the bottom of the meniscus reaches the zero line. Be sure to keep the meniscus at eye level.



Step 11: Touch the tip of the pipette to the inside of the 100 mL graduated cylinder. Keep the pipette vertical. Rotate your finger and allow the liquid to drain slowly until the meniscus reaches the desired volume.

Step 12: Tilt the pipette toward yourself and remove it from the graduated cylinder.

Step 13: Drain the remainder of the solution into the waste beaker.

Practise transferring various volumes of tap water. You might choose volumes such as 5 mL, 2 mL, 7.2 mL, and 4.6 mL.

Now that you know the steps and reasons for precise solution preparation, you can practise making a solution by dissolving a solid or by diluting a concentrated solution.

Investigation: Preparing and Diluting Solutions

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

PATHWAYS

If you have access to laboratory facilities, do Part A. If you do not have access to laboratory facilities, do Part B.



Part A involves doing all the components of Activity 7.3, Preparing and Diluting Solutions on pages 272 and 273 of your textbook.

Part B involves doing some components of Activity 7.3 with some alternative procedures.

Part A

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☑ F. Evaluating

Purpose

To prepare a 0.100 mol/L copper(II) sulphate solution from solid copper(II) sulphate pentahydrate and to dilute a sufficient 3.0 mol/L hydrochloric acid solution to prepare 100 mL of 0.10 mol/L hydrochloric acid solution

Background Information



When diluting the hydrochloric acid solution in this investigation, remember to fill the volumetric flask or graduated cylinder three-quarters full of distilled water before you add the acid.

Materials

The materials are listed on page 273 of *Visions* 2.

Procedure

- Follow the Planning and Procedure sections on pages 272 and 273 of *Visions* 2. Use a stirring rod to mix the solution if you are preparing the solution in a graduated cylinder.
- To compare your copper(II) sulphate solution with the standard solution, pour the same amount of each into test tubes of the same size and view each from the top. Use a white sheet of paper for a background.

- Use the graduated pipette to transfer the calculated amount of hydrochloric acid into the volumetric flask or graduated cylinder. Refer back to the steps describing how to use a graduated pipette if you are having difficulty.

- Rinse all glassware, plastic containers, and equipment thoroughly after use.

Observations

11. List any differences between the standard and the copper(II) sulphate solution that you prepared.

12. State the pH value of the diluted hydrochloric acid solution.

Analysis and Interpretation

13. Show the calculation of Step 1 of the Procedure section in the textbook.

14. Show the calculation of Step 3 of the Procedure section in the textbook.

15. What should the pH of the diluted acid solution be?

16. List some possible sources of error in your technique that would make the solution different than the standard sample.

Check your answers by turning to the Appendix, Section 2: Activity 2.

End of Part A

Part B

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☑ F. Evaluating

Purpose

Prepare a 0.100 mol/L copper(II) solution from solid copper(II) sulphate pentahydrate and dilute a sufficient quantity of this 0.100 mol/L solution to make a 0.0200 mol/L copper sulphate solution.

Materials

- copper(II) sulphate pentahydrate, $CuSO_4 \bullet 5H_2O_{(s)}$
- 10 mL graduated pipette
- 100 mL volumetric flask or graduated cylinder
- 2 – 100 mL beakers
- distilled water
- balance
- 3 small test tubes
- glass stirring rod

VISIONS

Procedure

Follow the Planning and Procedure sections on pages 272 and 273 of *Visions* 2.

Step 1: Do Steps 1 and 2 in the Procedure section on page 273 of *Visions* 2. Use a stirring rod to mix the solution if you are using a graduated cylinder to prepare the solution. To compare your copper(II) sulphate solution with the standard solution, pour the same amount of each into test tubes of the same size and view each from the top. Use a white sheet of paper for a background. Instead of diluting an aqueous solution of hydrochloric acid, you will be diluting the 0.100 mol/L $CuSO_{4(aq)}$ that you make in Step 1 in this investigation.

Step 2: Substitute the following for Step 3 of the Procedure section on page 273 of *Visions* 2.

- Calculate the volume of 0.100 mol/L $CuSO_{4(aq)}$ needed to make 100 mL of 0.0200 mol/L $CuSO_{4(aq)}$.

Step 3: Substitute the following for Step 4 of the Procedure section on page 273 of *Visions* 2.

- Prepare the solution and compare it to the more concentrated solution. Use the same volume in the same-sized test tubes.

Step 4: Rinse all glassware, plastic containers, and other equipment used for solutions thoroughly after use.

Observations

17. List any differences between the standard in the lab kit and the copper(II) sulphate solution that you prepared.

18. List any differences between the concentrated copper(II) sulphate solution that you prepared and the diluted one.

Analysis and Interpretation

19. Show the calculation for Step 1 of the Procedure section on page 273 of your textbook.

20. Show the calculation for Step 2 of the Procedure section in this investigation.

21. Explain what happens to the colour of the solution as you dilute it.

22. List some possible sources of error in your technique that would make the solution different than the standard sample.

Check your answers by turning to the Appendix, Section 2: Activity 2.

End of Part B

In this activity, you have learned how to make solutions using two different methods. One method is by dissolving a solid solute in distilled water, and the other method is by diluting a concentrated solution. In the next activity, you will see how knowledge about solutes can help you to make informed decisions.

Activity 3: How Much Is Too Much?

You have learned about molar concentration as well as specific units describing solutions that have very low solute concentrations. In environmental studies, concentration is described in parts per million (ppm) or even parts per billion (ppb). These units are used to describe chemicals that may be harmful even at very low concentrations.



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toxic – poisonous or harmful to living organisms

biomagnification – a process where a non-excretal substance increases in concentration as it is passed up the food chain

Toxic substances, such as the pesticide being applied in the previous photograph, can be harmful even in low concentrations because they can collect in the tissues of small animals and be passed up the food chain. Recall from Module 3 that in the transfer of energy from one trophic level to another, each level consumes a large number of the organisms in the level below. It is this consumption of a large number of organisms, each with a small amount of a toxic substance, that leads to a process called **biomagnification**. Each succeeding level in the food chain accumulates larger and larger amounts of the toxic substance. The organisms at the top of the food chain accumulate the most.

In some cases, however, applications of chemicals such as the pesticide being applied in the photograph may be necessary to save the forest. Without the forest, few of the organisms that live there will survive. Thus, society needs to balance the good that toxic substances such as pesticides, herbicides, and heavy metals provide, with the harm they can cause.

risks – dangerous elements or factors

benefits – factors that are helpful or promote well-being

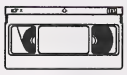
How should important decisions be made? One way to make an unbiased decision is to try and balance the **risks** against the **benefits**.

The difficulty in making an unbiased decision lies in how you perceive risk and how you evaluate benefits. Do you think riding a motorcycle or driving a car is risky? Do you think that driving a car involves more risk than smoking a cigarette? What benefits do you get from driving a car or from smoking?

PATHWAYS

If you have access to the video entitled *How Safe Is Enough?*, do Part A. If you do not have access to the video, do Part B.

Part A



To gain an understanding of how people perceive risk, view the video *How Safe Is Enough?* from Atomic Energy of Canada Ltd., 1983; then answer the following questions. You may find it useful to review the video a second time when answering the questions. This video may be purchased from Learning Resources Distributing Centre. You may also be able to abtain it through your local library or school.

1. How did the teacher suggest that the relative risk of activities be compared at the beginning of the film?

2. How were risks compared for the activities considered on the monitor?

3. Why did the students tend to misjudge the risk involved in the activities they were shown?

4. Information is required to judge the level of risk in an activity. What else determines how people finally evaluate the risk involved?

5. According to the film, what equation describes how risk can be estimated in order to predict future occurrences?

6. In addition to the level of risk involved, what other information about the activity should be considered?

7. a. What are three major steps necessary to form a reasonable evaluation of the best way to accomplish a task?

   b. What is the name of this method of analysis?[1]

Check your answers by turning to the Appendix, Section 2: Activity 3.

End of Part A

Part B

Are you interested in mountain climbing or sky diving? How risky are these activities? The video used in Part A discusses how the risk of various activities is perceived. Answer the following questions to help you understand your own perception of risk.

8. State what it means to you to describe something as being risky or having a high risk.

9. Can you think of any activities that are completely free of any risk?

10. Study the following columns of activities or items with various associated risks. Which column contains the activities or items involving higher risk?

Column 1	Column 2
• airplane travel	• car travel
• dioxins	• diabetes
• radiation (other than natural background)	• smoking
• Three Mile Island	• falls (people under 65)
• poisoning by insecticides	• circulatory disease (people under 65)
• Love Canal	
• nuclear waste	

[2]

[1] Text for questions 1 through 7 taken from *On the Perception, Estimation and Evaluation of Risk.* Reprinted with permission from Atomic Energy of Canada Ltd., 1983.

[2] Text taken from *On the Perception, Estimation and Evaluation of Risk.* Reprinted with permission from Atomic Energy of Canada Ltd., 1983.

11. The following is a list of activities or items which have various degrees of risk.

A SURVEY OF RISK PERCEPTIONS	
Activity or Item	**Your Perception of Actual Risk**
drinking alcoholic beverages	
riding a bicycle	
flying on commercial flights	
using electric power in the home	
fire fighting	
handguns	
hunting	
motorcycles	
motor vehicles	
nuclear power	
smoking	
swimming	

a. Complete a chart like the previous one and rank the activities or items from 1 to 12 in terms of your perception of actual risk. Use 1 for the activity or item of highest risk.

b. How does your ranking compare to the ranking given by other people?

c. How does your ranking compare to the ranking by actual or estimated fatalities?

d. Based on actual or estimated fatalities, which activity is most risky?

e. Which activity did you have as being the most risky? On what did you base your perceptions of the risk of smoking?

[1] Chart taken from *On the Perception, Estimation and Evaluation of Risk.* Reprinted with permission from Atomic Energy of Canada Ltd., 1983.

From these questions you can see that your perception of what activity is risky is not necessarily based on the actual number of deaths per year, but may be based on an emotional perception of the risk of this activity.

Basing risk on actual numbers of deaths per year is better than basing the perception of risk on emotion. However, there are other difficulties with perception based on actual or best estimated deaths per year. Compare the following tables.

TABLE 5.5 DEATHS PER YEAR FOR VARIOUS ACTIVITIES

Activity	Deaths Per Year (best estimates)
Scuba diving	132
Sport parachuting	45.1
Flying home-built aircraft	23
Football	17.7
Motorcycle racing	17.5
Stock car racing	10.3
Hot air ballooning	3.0
Airplane aerobatics	1.8
Airplane pylon racing	1.4
Bobsledding	0.1

[1]

TABLE 5.6 DEATHS PER YEAR PER 100 000 PARTICIPANTS FOR VARIOUS ACTIVITIES

Activity	Deaths Per Year Per 100 000 Participants
1. Airplane pylon racing	1570
2. Flying home-built aircraft	1000
3. Airplane aerobatics	900
4. Stock car racing	400
5. Hot air ballooning	150
6. Sport parachuting	149
7. Bobsledding	100
8. Scuba diving	27.7
9. Motorcycle racing	14.0
10. Football	0.9

[2]

Chart taken from *On the Perception, Estimation and Evaluation of Risk.* Reprinted with permission from Atomic Energy of Canada Ltd., 1983.
Ibid.

12. Which activity has the highest risk in the table ranked by deaths per year?

13. How does the risk of scuba diving rank based on deaths per 100 000 participants?

14. How risky is playing football compared to flying a home-built aircraft based on deaths per year?

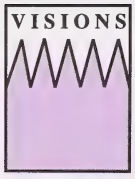
15. How risky is flying a home-built aircraft compared to playing football based on deaths per 100 000?

16. Which comparison do you feel gives a truer sense of the risk of the activity?

Check your answers by turning to the Appendix, Section 2: Activity 3.

End of Part B

Some expert opinions may be needed and some facts that are not usually known may need to be researched. In order to do a well-balanced risk-benefit analysis, you must consider all the factors that have an affect on the situation. The use of data that contains concentrations in units of ppb or mol/L is useful only if you have an idea of the amounts they represent. What do you do once you have a list of facts and figures?



Read the article Are Our Safety Standards Too High? on pages 264 and 265 of *Visions* 2.

17. What are some of the risks that can occur if you drink the bottled water?

18. What are some of the benefits that can occur if you drink the bottled water?

19. Compare the benefits and the risks of drinking the bottled water mentioned in the article. Decide whether or not you would drink the water. Explain your reasons in a couple of sentences.

20. Set up a chart that compares the risks and the benefits of using a growth hormone to protect fruit trees from insects. Decide whether or not you would use the hormone if you were operating an apple orchard. Explain your reasons in a couple of sentences.

21. Define and discuss *voluntary risk* and *involuntary risk*.

22. Answer question 2 on page 265 of your textbook.

Check your answers by turning to the Appendix, Section 2: Activity 3.

Some situations involving toxic substances may be closer to you than you realize. Do you have mercury or silver dental fillings? A controversy has been growing over the past few years about the safety of dental fillings which use mercury. In 1992, Germany banned the use of mercury in dental fillings.

Mercury is a highly toxic substance that causes nerve damage, yet is present in the environment. People pass 0.0076 mg of mercury in their urine daily. There are maximum concentrations recommended for mercury in drinking water. In Alberta, the maximum concentration is 0.001 mg/L.

To learn more about the controversy surrounding tooth fillings, read the article which follows question 23 entitled "Mercury Leak."

23. Make up and complete an inventory chart similar to the one that follows. In the Points Which Support the Use of Hg column, fill in some information that supports the use of mercury fillings. In the Points Which Oppose the Use of Hg column, fill in some information that goes against the use of mercury fillings. In the interesting-points column, write down some things that you find interesting about the article. You will be using your inventory in a later question.

Inventory

ISSUE: SHOULD MERCURY BE USED IN DENTAL FILLINGS?		
Points Which Support Use of Hg	**Points Which Oppose Use of Hg**	**Interesting Points**

Check your answers by turning to the Appendix, Section 2: Activity 3.

Mercury Leak

American study backs claim that most mercury in body comes from dental fillings

By Mark Lowey
(Herald writer)

People are exposed to more mercury from tooth fillings than from diet or any other source, says a new American study prompted by Calgary scientists' research.

More studies should be conducted to determine whether there's enough mercury leaking from the widely used fillings to harm people, says University of Arizona toxicologist and study leader Dr. Vasken Aposhian.

"We don't know" whether the fillings are causing illness or disease, he said from Tucson.

"What we do know is that mercury is one of the most toxic substances around... there's no question more research should be done."

The U of Arizona study found two-thirds of the mercury in urine of people who have the fillings came from mercury vapour released by the restorative material.

Vapour escapes when people chew, grind or bush their teeth, and as the silver-coloured fillings – called dental amalgams – deteriorate with age.

People absorb between three to 17 micrograms of mercury per day from dental amalgam vapour, says a UN World Health Organization report on mercury.

"A great deal of the mercuric mercury was deposited finally in the kidneys," says the U of Arizona study.

But, it says, "there is no unequivocal evidence that such amounts of mercury in the human body are harmful to the individual's health."

The study is published in the prestigious Federation of American Societies for Experimental Biology Journal, whose editorial board includes Nobel Prize winners.

But a spokesperson for the Canadian Dental Association says people shouldn't worry about the amalgam fillings, made of a metal alloy containing 45- to 50-percent mercury.

"We have no reason to be concerned, said Dr. Ralph Barolet, chairman of the association's committee on dental materials.

The U.S. Food and Drug Administration and the U.S. National Institutes of Health have decided the fillings are safe, he said, "and we have no reason to believe otherwise."

Last August, a scientific panel from two branches of the National Institutes of Health said there's no solid scientific evidence showing the amount of vapour escaping from fillings causes any illness.

More study is needed, but "the present evidence suggests that the degree of exposure to mercury via dental amalgam is insufficient to be considered a health risk in virtually all individuals," said the panel's report.

A separate panel from the Food and Drug Administration reached essentially the same conclusion last April, although it also recommended more research.

Both panels' opinions are at odds with several peer-reviewed, published scientific studies by medical researchers at University of Calgary and elsewhere.

U of C research has shown dental mercury impairs kidney function in sheep, and that it collects in the kidneys, digestive tract and other organs of sheep and monkeys.

When the local research was first reported 1 1/2 years ago, the American Dental Association claimed dietary mercury in a tuna fish salad might be a bigger source of mercury exposure than dental fillings.

The U of Arizona study shoots down that claim, says U of C medical researcher Dr. Fritz Lorscheider. "If amalgams were not used, the levels of mercury in the human body would only be one-third of what they are now."

"There's a risk associated with all heavy-metal exposure," Lorscheider noted.

There are now at least six North American universities, including U of C, investigating possible health hazards of dental mercury.

University of Kentucky's Sanders-Brown Centre on Aging just received a National Institutes of Health grant worth more than $800,000 over five years, to investigate a possible link between dental mercury and Alzheimer's disease.

U of Kentucky scientists have found abnormally high levels of mercury in the brains of autopsied Alzheimer's victims.

In Sweden, research has shown people's kidney function improves after the fillings are removed. Also in Swedish studies, there are signs of impaired brain development and learning ability in laboratory animals exposed to mercury vapour.

In the latest study at U of Arizona, scientists gave an orally administered 'chelating' drug to two volunteer groups, each consisting of 10 university students.

The drug, called DMPS, chemically binds with and removes mercury from body tissues.

The drug is not approved for treating patients in Canada or the U.S., although it is used in Russia and Germany. U of Arizona scientists obtained a special licence to use DMPS in research.

Even before receiving the drug, 10 students with amalgam fillings had almost three times more mercury in their urine compared with 10 students without fillings.

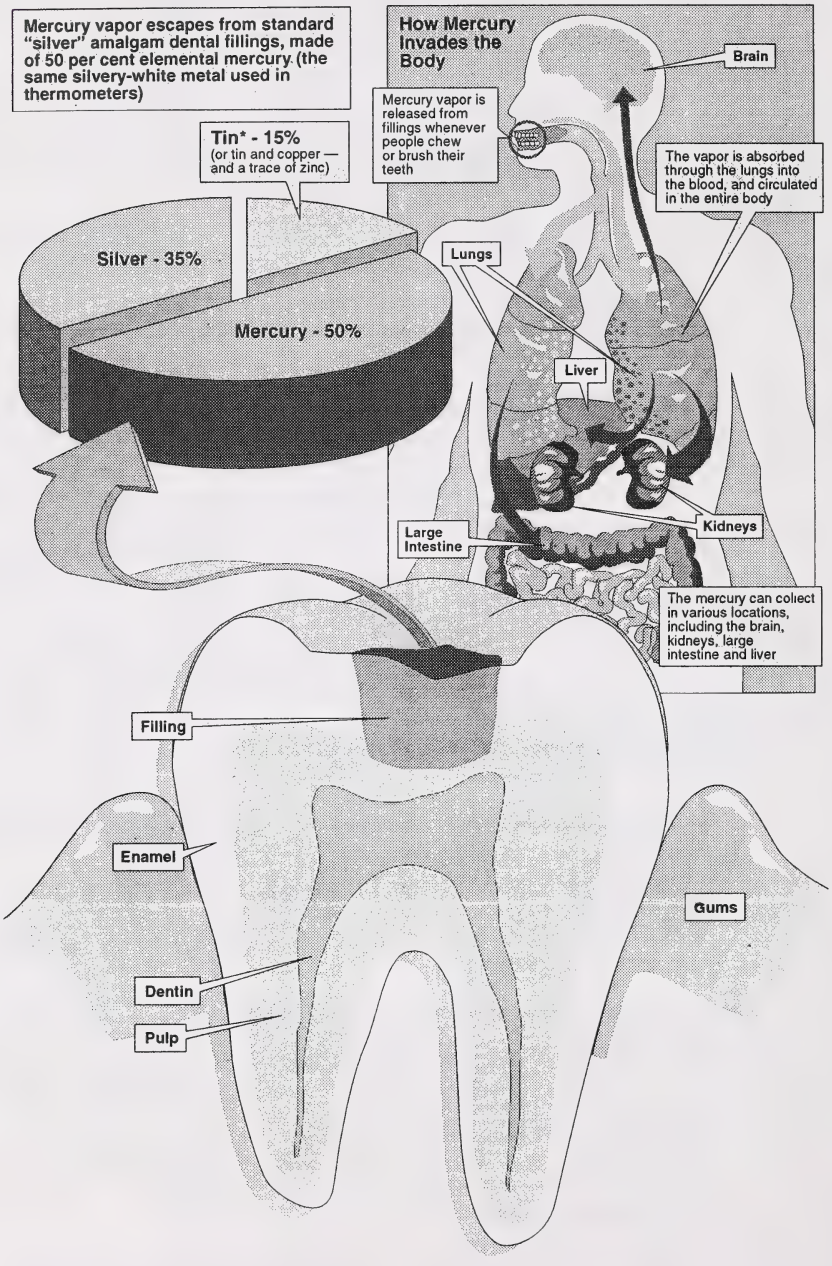
Nine hours after getting the drug, the fillings group excreted 3.4 times more urinary mercury compared with the non-fillings group.

A statistical check revealed a strong correlation or match between the number of amalgams the fillings group had, and the amount of mercury in the urine.

"There's no question that there is a relationship between the surface area of the amalgams and the amount of mercury in the body," said study leader Aposhian.

He said DMPS should be investigated as a potentially useful tool to measure the amount of mercury and other heavy metals such as lead and arsenic in the human body.

SILVER AMALGAM DENTAL FILLINGS



1

[1] *The Calgary Herald* for the article "Mercury Leak" by Mark Lowey from May 23, 1992, page G9. Reprinted by permission of *The Calgary Herald*.

24. a. Mercury is passed in the urine of people with fillings. What fraction is caused by dental amalgams?

    b. How does mercury vapour escape from fillings?

    c. According to the UN World Health Organization, _____ of mercury is absorbed by people daily from dental fillings.

25. List three organizations that have decided mercury fillings are safe.

26. List three universities that are researching the effects of mercury in dental fillings.

27. If you have many fillings in your mouth, what does this mean about the amount of mercury found in your body?

Check your answers by turning to the Appendix, Section 2: Activity 3.

In the next part of this activity, you will be performing a qualitative assessment of the risks of mercury fillings, based on the mercury filling article you have examined. A risk assessment allows you to make careful judgements on important issues. The issue you will try resolving is as follows:

> Should I remove the fillings in my mouth and have them replaced with gold or porcelain fillings?

The next two questions will guide you through the steps involved in performing a risk assessment. Use the points you entered in your inventory.

28. a. List the risks involved in removing and replacing the fillings.

    b. List the benefits involved in removing and replacing the fillings.

    c. Your next task is to decide whether the benefits of mercury fillings outweigh the risks. This decision will depend on the number of benefits compared to the number of risks and how important you perceive each risk and benefit to be. The end decision is yours and you should be able to back up your decision with reasonable arguments and evidence.

29. Based on the risk assessment you have performed, would you have your fillings removed and replaced? Explain.

Check your answers by turning to the Appendix, Section 2: Activity 3.

In this activity you learned that great precautions must be taken with some toxic substances. You also learned that you may have to make various judgements throughout your lifetime as to whether the usefulness of some things outweigh the risks.

Follow-up Activities

If you had difficulties understanding the concepts in these activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

Solutions can be made in two major ways: dissolution and dilution.

Dissolution	Dilution
• Start with a solid (usually). • Use a balance and a volumetric flask or graduated cylinder. • Calculate the mass of solute needed to make a certain volume. • Use unit analysis or use the formulas $n = CV$ and $m = nM$. $n = CV$ $\quad$ $m = nM$ $= \text{mol/L} \times \text{L}$ $\quad$ $= \text{mol} \times \text{g/mol}$ $= \text{mol}$ $\quad$ $= \text{g}$	• Start with a concentrated solution. • Use a graduated pipette and a volumetric flask or a graduated cylinder. • Calculate the volume of the concentrated solution you need to dilute. • Use the formula $C_1V_1 = C_2V_2$. $V_1 = \frac{C_2V_2}{C_1}$ $= \frac{\text{mol/L} \times \text{L}}{\text{mol/L}}$ $= \text{L}$

1. You are asked to make 100 mL of 0.500 mol/L $CaCl_{2(aq)}$ from a supply of $CaCl_{2(s)}$.

   a. Should you perform a dilution or should you dissolve a solid?

   b. Determine how much $CaCl_{2(s)}$ you would need.

   c. Using the information in Skill 12 of Appendix A on page 537 of your textbook, draw a flow chart to show how you would make the solution.

VISIONS

2. You are given a stock solution of 3.0 mol/L $NaOH_{(aq)}$. You are then asked to make 250 mL of 0.20 mol/L $NaOH_{(aq)}$.

   a. Should you perform a dilution or should you dissolve a solid?

   b. How many millilitres of 3.0 mol/L $NaOH_{(aq)}$ would you need?

   c. Using the information in Skill 11 of Appendix A on page 536 of your textbook and the modification presented in this section, draw a flow chart to show how you would make the solution.

VISIONS

3. List four units of concentration other than mol/L.

4. Convert the following units into the unit indicated.

   a. 350 mL to litres
   b. 1050 g to kilograms
   c. 2.50 L to millilitres
   d. 2.05×10^3 g to kilograms

5. A household pesticide is used to kill carpet beetles in an old apartment building. It is well documented that 1 in 3000 people are highly sensitive to the spray. At high concentrations, it can be deadly. Carpet beetles can infest rugs, mattresses, sofas, and other furniture. You can find their shells around a home that is infected.

   a. List as many risks as possible that you can think of that you would consider important when deciding whether or not to use the spray.

   b. List as many benefits as possible.

   c. Weigh the risks and benefits to justify whether or not you would use the household pesticide.

Check your answers by turning to the Appendix, Section 2: Extra Help.

Enrichment

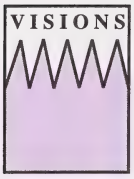
Do any two of the following five questions.

1. Research a project in your area which may have caused controversy due to possible air pollution, water pollution, or underground water contamination. The situation may involve a project which was completed, a project which was proposed but has not yet begun, or even a project which was proposed and abandoned. If there is no such project that you know of in your area, then research a newspaper or magazine article regarding some controversial project in Alberta. Write a report describing the situation and list the risks and benefits of the project. Decide whether or not you would support the project.

2. Sugar is often listed as the reason why one drink is considered healthier than another. Sucrose $(C_{12}H_{22}O_{11})$ is a common sugar used in soft drinks; but in juices, there can be a variety of sugars.

   a. Read a label of a juice container and locate the sugar content. Calculate the concentration of sucrose in the juice. Assume that all the sugar in the juice is sucrose.

   b. If the concentration of sucrose in a can of pop is 0.30 mol/L, which beverage contains the most sugar, the juice or the pop?



3. Do question 14 on page 270 of *Visions* 2.

4. Fragrances and their design is a multimillion dollar industry. In technical terms, a fragrance is composed of three elements:

   - the vehicle (usually ethyl alcohol)
   - the fixative (a substance that holds the scent on the skin for a long period of time)
   - the essential (a mixture of substances that produce the scent)

   Fragrances that you wear may contain a mixture of 50 to 300 different substances. So that a primary smell is violets, one common fragrance contains 237.5 g of ionine $(C_{13}H_{20}O_{(s)})$ dissolved in 450 kg of ethyl alcohol. The fixative is a variety of plant oils.

   a. What is the solute and what is the solvent in this fragrance?

   b. What is the concentration of the essential in terms of percent by mass and in terms of parts per million?

   c. What is the concentration of ionine in mol/L? Use $1\,kg \doteq 1\,L$ for ethyl alcohol.



5. View the video entitled *S.T.S. Toxilla* available from Access Network, and answer the following questions. This video looks at the problems of toxic substances and how these problems are being dealt with in Alberta. You will find it useful to review the questions before you watch the video. View the video a second time as you answer the questions. You may be able to obtain this video through your local library or school.

   a. What is *toxicity*?

   b. List the five ways in which toxic substances can be classified, and give one example of each.

   c. Why are batteries such a great hazard to the environment?

d. What has the battery industry done in recent years to reduce the problems caused by batteries?

e. How does the amount of toxic substances put into the environment by people compare to the amount put in by industry? Why?

f. What is the purpose of the Alberta Special Waste Treatment Centre in Swan Hills?

g. How does the Alberta Special Waste Treatment Centre eliminate hazardous wastes?

Check your answers by turning to the Appendix, Section 2: Enrichment.

Conclusion

The concentration of a solute in a solution can be described in a number of different ways depending on the amount. In a chemistry lab, the most common method is in terms of moles per litre. Aqueous solutions are made by either dissolving a solid in water or by diluting a concentrated solution with water.

In each case, there is a precise way of making a solution. In the next section, you will learn how reactions in solution can be used as recipes.

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 2.

Section

3

Stoichiometry – Using Chemical Equations



WESTFILE INC.

Have you ever waited a long time for your food in a restaurant? Even though you may be hungry, are you more concerned about the quality or quantity? Are you prepared to wait for just a few more minutes until the chefs have made the meals to their liking?

In some ways, chemistry can be compared to cooking. If you are going to produce a chemical, you must take similar precautions to what a chef takes. You must be able to understand basic recipes, and be able to adjust them for various amounts.

In this section, you will learn about the recipes used in chemistry, and the ways that you can use the recipes to adjust the amounts of substances.

Activity 1: Balancing Chemical Equations

Chili for Four

300	mL	chopped onions
125	mL	chopped celery
125	mL	mushrooms
125	mL	green pepper
6	mL	chopped garlic
250	g	ground beef
500	mL	canned tomatoes
125	mL	tomato paste
250	mL	kidney beans
20	mL	chili powder
1	mL	ground cumin
2.5	mL	basil
2.5	mL	paprika

Method: Fry the vegetables and the garlic with the ground beef for five minutes. Then, add all the other ingredients, cover, and simmer for one hour.

If you have the previous recipe, what do you do if you need to make a meal for twelve friends? Do you make the meal again and again until you have enough for twelve?

1. What volume of kidney beans will you need if you change the recipe so that you can feed twelve people?

2. What volume of basil will you need in a recipe for twelve people?

3. What number of people could you feed if you were going to use 1.0 L of kidney beans?

Check your answers by turning to the Appendix, Section 3: Activity 1.

Adjusting the chili recipe involves a process similar to what chemists use. The recipes that chemists use are the balanced chemical equations. These equations describe the amounts of the reactants and also the amounts of what is made. The comparison of the recipe for chili to a balanced chemical equation is shown as follows:

300 mL onions + 125 mL celery + 125 mL mushrooms... → chili for four
ingredients → prepared meal
before preparation → after preparation

Compare this to the formation of ammonia.

$$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$$

reactants → products
before reaction → after reaction

reactants – substances that interact to break and reform bonds in the preparation of new chemical substances
The reactants are on the left side of the arrow in a balanced chemical equation.

products – substances that are the result of a chemical reaction
The products are on the right side of the arrow in a balanced chemical equation.

4. Which part of the chemical equation is similar to the number of mL in the recipe?
5. What is the name used for the ingredients of a chemical reaction?
6. What part of a chemical equation is similar to the dish?

Check your answers by turning to the Appendix, Section 3: Activity 1.

VISIONS

Like a recipe, a chemical equation can tell you many things. Read pages 274 and 275 of *Visions 2* to learn more about interpreting chemical equations.

7. What is the definition of *stoichiometry*?
8. List three pieces of information in a chemical equation.
9. According to the information in the textbook, the ratio of reactants to products in the reaction between methane $\left(CH_{4(g)}\right)$ and steam $\left(H_2O_{(g)}\right)$ to produce carbon monoxide $\left(CO_{(g)}\right)$ and hydrogen $\left(H_{2(g)}\right)$ is 1:1:1:3. Study the equation in the textbook to see how this ratio is obtained; then write the ratio of reactants to products for the following reactions.

   a. $N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$

   b. $Ca(NO_3)_{2(aq)} + Na_2CO_{3(aq)} \rightarrow CaCO_{3(s)} + 2NaNO_{3(aq)}$

   c. $Ni_{(s)} + 2AgNO_{3(aq)} \rightarrow 2Ag_{(s)} + Ni(NO_3)_{2(aq)}$

   d. $2Al_2O_{3(s)} \rightarrow 4Al_{(s)} + 3O_{2(g)}$

10. Balance the following equations; then interpret the equations in terms of moles. For example, the reaction between methane and steam can be interpreted as one mole of methane gas reacting with one mole of steam to form one mole of carbon monoxide gas and three moles of hydrogen gas.

    a. $\_\_NaCl_{(s)} \rightarrow \_\_Na_{(s)} + \_\_Cl_{2(g)}$

    b. $\_\_HCl_{(aq)} + \_\_Ba(OH)_{2(aq)} \rightarrow \_\_BaCl_{2(aq)} + \_\_H_2O_{(l)}$

    c. $\_\_Pb_{(s)} + \_\_AgNO_{3(aq)} \rightarrow \_\_Pb(NO_3)_{2(aq)} + \_\_Ag_{(s)}$

    d. $\_\_H_{2(g)} + \_\_O_{2(g)} \rightarrow \_\_H_2O_{(l)}$

    e. $\_\_H_3PO_{4(aq)} + \_\_KOH_{(aq)} \rightarrow \_\_K_3PO_{4(aq)} + \_\_H_2O_{(l)}$

Check your answers by turning to the Appendix, Section 3: Activity 1.

When you are adjusting chemical equations, you can multiply the moles just like you did for any of the ingredients in the chili recipe. The coefficients, or the number of moles in a balanced equation, represent the amount.

11. Answer the following questions given the following equation:

    $4Al_{(s)} + 3O_{2(g)} \rightarrow 2Al_2O_{3(s)}$.

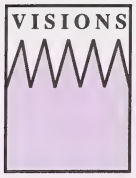
    a. How many moles of $Al_{(s)}$ should you react to make four moles of $Al_2O_{3(s)}$?

    b. How many moles of $O_{2(g)}$ should you react to make six moles of $Al_2O_{3(s)}$?

Check your answers by turning to the Appendix, Section 3: Activity 1.

The previous two questions are meant to show that you can work out these answers in your head. Calculating the amounts in a chemical equation is called stoichiometry. This is like calculating the amounts of an item required to double or triple a chili recipe.

Even though you can calculate some of these calculations in your head, you may need a formal way to show your work. The textbook uses the unit analysis method to show how to calculate the stoichiometry problems. This method will be included in the answers in the Appendix.



To learn how to show these calculations using the unit analysis method, read page 276 of *Visions* 2.

12. Use the given balanced equation to decide on the conversion factors needed.

    a. $H_3PO_{4(aq)} + 3LiOH_{(aq)} \rightarrow Li_3PO_{4(aq)} + 3H_2O_{(l)}$

    What are the conversion factors relating phosphoric acid and water?

    b. $2Fe_2O_{3(s)} \rightarrow 4Fe_{(s)} + 3O_{2(g)}$

    What are the conversion factors relating the iron(III) oxide to the oxygen?

    c. $Sr(NO_3)_{2(aq)} + Na_2CO_{3(aq)} \rightarrow SrCO_{3(s)} + 2NaNO_{3(aq)}$

    What are the conversion factors relating the strontium nitrate to the sodium nitrate?

13. Calculate the number of moles using the conversion factor from the given balanced equation.

    a. $Ni_{(s)} + 2AgNO_{3(aq)} \rightarrow 2Ag_{(s)} + Ni(NO_3)_{2(aq)}$

    How many moles of silver can be produced from 0.200 mol of nickel?

    b. $2Al_2O_{3(s)} \rightarrow 4Al_{(s)} + 3O_{2(g)}$

    If 0.16 mol of aluminum is formed, how many moles of oxygen are produced?

    c. $Sr(NO_3)_{2(aq)} + Na_2CO_{3(aq)} \rightarrow SrCO_{3(s)} + 2NaNO_{3(aq)}$

    If 0.324 mol of dissolved strontium nitrate reacts, how many moles of strontium carbonate precipitates?

    d. $H_3PO_{4(aq)} + 3LiOH_{(aq)} \rightarrow Li_3PO_{4(aq)} + 3H_2O_{(l)}$

    How many moles of dissolved lithium hydroxide will react with 2.3×10^{-4} mol of phosphoric acid?



14. Do questions 1 to 5 on page 277 of *Visions* 2.

Check your answers by turning to the Appendix, Section 3: Activity 1.

This activity has introduced the basic concepts involved in stoichiometry. In the next activity, you will learn how stoichiometry can be applied and measured in the lab.

Activity 2: Stoichiometry

In the last activity, you defined stoichiometry in terms of mole relationships. In this activity, you will see stoichiometry as a way to determine the masses of chemicals.

1. What is the name of the equipment used in the laboratory that measures the mass of a chemical?

2. What is the conversion used to change moles into grams?

3. Did the mole ratio change when different quantities were used in the stoichiometric calculations in the previous activity?

Check your answers by turning to the Appendix, Section 3: Activity 2.

The following gives two common questions usually answered by stoichiometric calculations.

- What mass of *reactant* is needed for the reaction?

  In some cases, you may need to know exactly how much of a chemical you need so that all of the others will react. You may also need to know how much of a chemical to use to make enough product.

- What is the mass of one of the *products*?

  In this case, you are calculating how much product you expect to be produced. You need to calculate the mass of the product.

heoretical yield – he calculated hass of a roduct

Whether you are calculating the mass of one of the reactants or the mass of one of the products, you need to use the balanced equation for the reaction. If you are calculating the mass of one of the products, then you are calculating the **theoretical yield**.

Stoichiometric Calculations

The answers to the previous two questions summarize all the calculations that you have been using so far in this module. The examples that follow use the unit analysis method and then the formula method to show how each step is done.

VISIONS

To see an overview of how the calculations are done, look at Figure 7.8 on page 278 of *Visions 2*. Using Figure 7.8, answer the following questions.

4. To convert Grams A to Moles A, you must use _____.

5. To convert Moles A to Moles B, you must use the _____.

6. What part of the balanced chemical equation is the mole ratio taken from?

7. To convert Moles B to Grams B, you must use _____.

Check your answers by turning to the Appendix, Section 3: Activity 2.

Example:

$H_3PO_{4(aq)} + 3LiOH_{(aq)} \rightarrow Li_3PO_{4(aq)} + 3H_2O_{(l)}$

What mass of dissolved lithium hydroxide will react with 4.90 g of aqueous hydrogen phosphate?

The solution is as follows:

Calculate the number of moles of $H_3PO_{4(aq)}$.

$$\text{molar mass} = [(3 \times 1.01) + (30.97) + (4 \times 16.00)]\ \text{g/mol}$$
$$= 98.00\ \text{g/mol}$$

$$4.90\ \cancel{\text{g}} \times \frac{1\ \text{mol}}{98.00\ \cancel{\text{g}}} = 0.0500\ \text{mol}$$

Calculate the number of moles of $LiOH_{(aq)}$.

$$0.0500\ \cancel{\text{mol of } H_3PO_{4(aq)}} \times \frac{3\ \text{mol of } LiOH_{(aq)}}{1\ \cancel{\text{mol of } H_3PO_{4(aq)}}} = 0.150\ \text{mol of } LiOH_{(aq)}$$

Calculate the mass of $LiOH_{(aq)}$.

$$\text{molar mass} = (6.94 + 16.00 + 1.01)\ \text{g/mol}$$
$$= 23.95\ \text{g/mol}$$

$$0.150\ \text{mol} \times \frac{23.95\ \text{g}}{1\ \text{mol}} = 3.59\ \text{g} \quad (3\ \text{significant digits})$$

Note: Remember to carry all the digits in your calculator as you proceed from one step to the next.

The previous example can also be done using the formula method. The formula method is as follows:

$1H_3PO_{4(aq)}$	$3LiOH_{(aq)}$
$M = [(3 \times 1.01) + (30.97) + (4 \times 16.00)]\ \text{g/mol}$ $= 98.00\ \text{g/mol}$	$M = (6.94 + 16.00 + 1.01)\ \text{g/mol}$ $= 23.95\ \text{g/mol}$
$m = 4.90\ \text{g}$	$m = ?$

$$n = \frac{m}{M} = \frac{4.90\ \text{g}}{98.00\ \text{g/mol}}$$
$$= 0.0500\ \text{mol}$$

$$0.0500\ \text{mol} \times \frac{3\ \text{mol of } LiOH_{(aq)}}{1\ \text{mol of } H_3PO_{4(aq)}} = 0.150\ \text{mol}$$

$$m = nM = 0.150\ \text{mol} \times 23.95\ \text{g/mol}$$
$$= 3.59\ \text{g} \quad (3\ \text{significant digits})$$

Example:

$Ni_{(s)} + 2AgNO_{3(aq)} \rightarrow 2Ag_{(s)} + Ni(NO_3)_{2(aq)}$

What is the theoretical yield of silver if 1.17 g of nickel reacts with the aqueous silver nitrate solution?

The solution is as follows:

Calculate the number of moles of $Ni_{(s)}$.

molar mass = 58.71 g/mol

$$1.17 \cancel{\text{g}} \times \frac{1 \text{ mol}}{58.71 \cancel{\text{g}}} = 0.019\,928 \text{ mol}$$

Calculate the number of moles of $Ag_{(s)}$.

$$0.019\,928 \cancel{\text{mol of Ni}_{(s)}} \times \frac{2 \text{ mol of Ag}_{(s)}}{1 \cancel{\text{mol of Ni}_{(s)}}} = 0.039\,857 \text{ mol of Ag}_{(s)}$$

Calculate the mass of $Ag_{(s)}$.

molar mass = 107.87 g/mol

$$0.039\,857 \cancel{\text{mol}} \times \frac{107.87 \text{ g}}{1 \cancel{\text{mol}}} = 4.30 \text{ g (3 significant digits)}$$

The previous example can also be done using the formula method. The formula method is as follows:

$1Ni_{(s)}$	$2Ag_{(s)}$
$M = 58.71 \text{ g/mol}$	$M = 107.87 \text{ g/mol}$
$m = 1.17 \text{ g}$	$m = ?$

$$n = \frac{m}{M} = \frac{1.17 \text{ g}}{58.71 \text{ g/mol}} = 0.019\,928 \text{ mol}$$

$$0.019\,928 \text{ mol} \times \frac{2 \text{ mol of Ag}_{(s)}}{1 \text{ mol of Ni}_{(s)}} = 0.039\,857 \text{ mol}$$

$$m = nM = 0.039\,857 \text{ mol} \times 107.87 \text{ g/mol} = 4.30 \text{ g (3 significant digits)}$$

8. After going over the examples, list three steps that are common to the calculations when you are given grams and asked for grams.

VISIONS

9. Now that you know how to calculate the mass of chemicals using the balanced equation, do all of questions 1 and 2 on page 279 of *Visions 2* as a practice before doing the activity to test a theoretical yield.

Check your answers by turning to the Appendix, Section 3: Activity 2.

In the next investigation, you will learn how to calculate the percent yield. To calculate the theoretical yield, you need to use stoichiometry. To find out the actual yield, you will have to carry out a procedure in the lab.

PATHWAYS

If you have access to laboratory facilities, do Part A. If you do not have access to laboratory facilities, do Part B.

VISIONS

Part A involves doing all the components of Activity 7.4 on pages 280 and 281 of *Visions 2*.

Part B involves doing an alternative investigation.

Part A

Investigation: Preparation of Ammonium Sulphate

Science Skills

- ☑ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☑ F. Evaluating

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

Purpose

Determine if the amount of a product obtained experimentally from a reaction is the same as the amount that is theoretically calculated.

Background Information

- Recall your skills of using a balance from Science 10.
- If you are using a balance with a precision of less than 0.01 g, your calculations will not be to three significant digits.

Prediction

10. Predict the mass of ammonium sulphate that can be prepared from 0.0100 mol of ammonia.

Materials

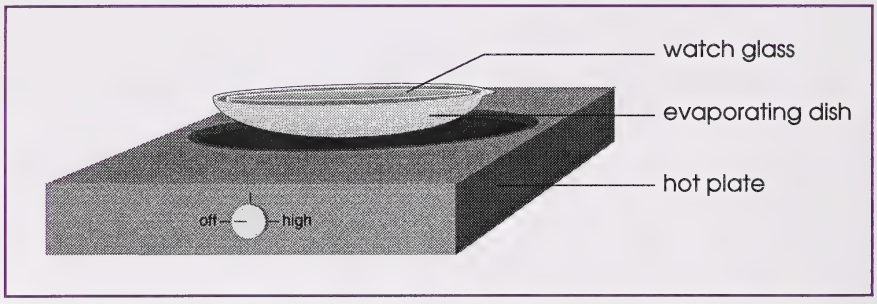
The materials are listed on page 281 of *Visions* 2.

Procedure

Follow the directions in the Planning and Procedure sections of Activity 7.4 on pages 280 and 281 of your textbook.

Caution

When heating the mixture in the evaporating dish, use a hot plate instead of the bunsen burner and retort stand apparatus.



Observations

11. Record the data in sentence form. Your answer should include answers to Steps 1, 7, and 8 in the Procedure section of your textbook.

Analysis and Interpretation

12. Answer questions 1 and 2 of the Analysis and Interpretation section on page 282 of your textbook.

13. Answer question 2 of the Extension section on page 282 of your textbook.

Check your answers by turning to the Appendix, Section 3: Activity 2.

End of Part A

Part B

Investigation: The Formation of Calcium Carbonate

Science Skills

- ☑ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☑ F. Evaluating

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

Purpose

Determine if the amount of a product obtained experimentally from a reaction is the same as the amount that is theoretically calculated.

Background Information

- The equal arm balance in the lab kit is accurate to 0.1 g.
- Recall your skills on balance use from Science 10.
- Use 2.0 g of sodium carbonate in this investigation.

Prediction

14. Write a balanced chemical equation; then calculate the theoretical yield of calcium carbonate when 1.5 g of calcium chloride reacts with the sodium carbonate solution.

Materials

- $CaCl_{2(s)}$
- $Na_2CO_{3(s)}$
- distilled water
- stirring rod
- 2 – 100 mL beakers
- funnel
- balance
- filter paper

Procedure

Step 1: Weigh out 1.5 g of calcium chloride.

Step 2: Dissolve 1.5 g of calcium chloride in 50.0 mL of distilled water.

Step 3: Weigh out and dissolve 2.0 g of sodium carbonate in 50.0 mL of distilled water.

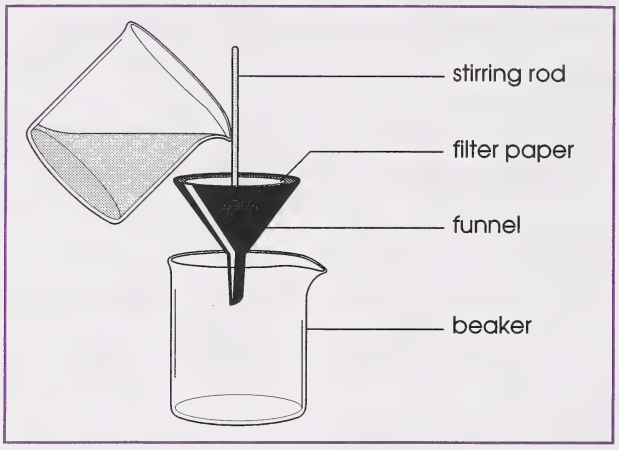
Step 4: Mix the two solutions together making sure each beaker has been rinsed into the mixture.

Step 5: Allow the precipitate to settle.

Step 6: Measure the mass of the filter paper.

Step 7: Place the filter paper in the funnel and pour the solution into the funnel to filter the precipitate. Be sure to rinse everything into the funnel.

Step 8: After allowing the precipitate to dry, measure the mass of the filter paper and the precipitate. (It may take a full day to dry the precipitate.)



Observations

15. Record the data in sentence form. Show how you found the mass of the precipitate.

Analysis and Evaluation

16. Was the mass of the calcium carbonate (the actual yield) equal to the theoretical yield? Account for any difference between the actual and theoretical yields.

17. Calculate the percent yield using the following formula.

$$\%\,\text{yield} = \frac{\text{actual mass}}{\text{predicted mass}} \times 100$$

Check your answers by turning to the Appendix, Section 3: Activity 2.

VISIONS

End of Part B

To learn about some reasons for low percent yields, read pages 282 and 283 of *Visions* 2.

18. List three reasons for a percent yield that is less than 100%.

19. The production of ammonia can be summarized by the following chemical equation:

$$N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$$

a. What is the theoretical yield if 100 g of nitrogen gas reacts?

b. If the actual yield is 105 g, what is the percent yield?

20. When aqueous solutions of barium hydroxide $\left(Ba(OH)_{2(aq)}\right)$ and sodium carbonate $\left(Na_2CO_{3(aq)}\right)$ are mixed together, the following reaction occurs:

$$Ba(OH)_{2(aq)} + Na_2CO_{3(aq)} \rightarrow 2NaOH_{(aq)} + BaCO_{3(s)}$$

a. If 2.50 g of sodium carbonate is dissolved to produce the $BaCO_{3(s)}$, what is the theoretical yield?

b. What is the percent yield if 4.32 g of precipitate is measured?

c. What mass of sodium carbonate would theoretically produce 4.32 g of $BaCO_{3(s)}$?

Check your answers by turning to the Appendix, Section 3: Activity 2.

Follow-up Activities

If you had difficulties understanding the concepts in these activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

1. Answer the questions that follow using the given balanced equation.

$$2Al_2O_{3(s)} \rightarrow 4Al_{(s)} + 3O_{2(g)}$$

a. Which number tells you the number of moles of aluminum oxide?

b. What is the molar mass of oxygen gas?

c. What is the molar mass of aluminum oxide?

d. What is the coefficient of the molecular formula for oxygen?

e. What number is the subscript in the molecular formula for oxygen gas?

The following is an example of using a balanced equation to find the number of moles.

Example: Calculations Using Mole Ratio

You are given the following balanced equation:

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)}$$

Thus, the mole ratio is 2:1:2.

How many moles of water will form when 1.35 mol of oxygen reacts with hydrogen?

The solution is as follows:

The mole ratio can be one of the following, depending on how the units cancel out.

$$\frac{1\text{ mol of } O_{2(g)}}{2\text{ mol of } H_2O_{(l)}} \text{ or } \frac{2\text{ mol of } H_2O_{(l)}}{1\text{ mol of } O_{2(g)}}$$

In this example,

$$1.35\ \cancel{\text{mol of } O_{2(g)}} \times \frac{2\text{ mol of } H_2O_{(l)}}{1\ \cancel{\text{mol of } O_{2(g)}}} = 2.70\text{ mol of } H_2O_{(l)}$$

Answer the following questions like the previous example.

2. a. $2Na_{(s)} + Cl_{2(g)} \rightarrow 2NaCl_{(s)}$

How many moles of sodium chloride will form when 0.300 mol of chlorine gas reacts with sodium?

b. $2Al_{(s)} + 6HCl_{(aq)} \rightarrow 2AlCl_{3(aq)} + 3H_{2(g)}$

How many moles of aluminum chloride will form if 0.600 mol of hydrochloric acid reacts with aluminum?

c. $2KOH_{(aq)} + H_2SO_{4(aq)} \rightarrow 2H_2O_{(l)} + K_2SO_{4(aq)}$

How many moles of $H_2SO_{4(aq)}$ will react with 0.400 mol of $KOH_{(aq)}$?

Check your answers by turning to the Appendix, Section 3: Extra Help.

The following steps show how a balanced chemical equation can be used to calculate the mass of any substance in the reaction:

Steps to Calculating the Mass of a Substance

Step 1: Calculate the number of moles of substance A by dividing the mass of substance A by the molar mass of substance A.

Step 2: Multiply the number of moles of substance A by the mole ratio to find the number of moles of substance B.

Step 3: Calculate the mass of substance B by multiplying the number of moles of substance B by the molar mass of substance B.

3. Answer the following questions using the three steps outlined previously.

a. $2Na_{(s)} + Cl_{2(g)} \rightarrow 2NaCl_{(s)}$

What mass of sodium chloride will form when 3.50 g of chlorine gas reacts with solid sodium?

b. $2Al_{(s)} + 6HCl_{(aq)} \rightarrow 2AlCl_{3(aq)} + 3H_{2(g)}$

How many grams of aluminum chloride will be produced if 2.70 g of aluminum reacts with hydrochloric acid?

c. $2KOH_{(aq)} + H_2SO_{4(aq)} \rightarrow 2H_2O_{(l)} + K_2SO_{4(aq)}$

What mass of $H_2SO_{4(aq)}$ will react with 2.80 g of dissolved potassium hydroxide $\left(KOH_{(aq)}\right)$?

The theoretical yield of a product of an experiment is calculated in question 3. To calculate the percent yield, you must first carry out an experiment and determine an actual yield. Percent yield is equal to actual yield divided by theoretical yield multiplied by 100.

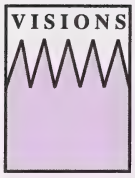
4. a. What is the formula for calculating the percent yield?

   b. If the theoretical yield of an experiment was 2.60 g of calcium carbonate and the student measured a mass of 2.55 g, what is the percent yield of calcium carbonate?

Check your answers by turning to the Appendix, Section 3: Extra Help.

Enrichment

Do any three of the next five questions.



1. Answer question 5 on page 283 of *Visions* 2.

2. Answer all of question 11 on page 286 of *Visions* 2.

3. Ammonia is one of the primary chemicals used in industry. Find which industries use ammonia and why.

4. A student produces 2.98 g of precipitate by reacting 3.50 g of calcium chloride solution with a concentrated solution of sodium phosphate. Calculate the percent yield of this experiment.

5. What mass of sodium hydroxide would completely neutralize 10.0 g of sulphuric acid, $H_2SO_{4(l)}$?

Check your answers by turning to the Appendix, Section 3: Enrichment.

Conclusion

In this section, you have learned that a balanced chemical equation is a useful tool in finding quantities. You learned that you can use a balanced equation and the concept of moles to predict the amount of a chemical that is required in a reaction or the theoretical yield of a reaction. This is the basis of stoichiometry.

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 3.

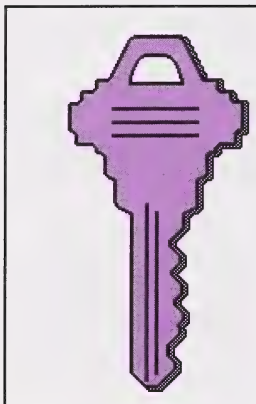
MODULE SUMMARY

In this module, you have taken an in-depth look at aqueous solutions. In Section 1 you investigated the various properties of solutions, and you can now classify solutions as being acidic, basic, or neutral.

In Section 2 you learned about the mole concept, and you learned how to prepare a solution by dissolving a solid in distilled water or by diluting a more concentrated solution. You also learned about the hazards of some materials, in particular those that accumulate in living systems.

In Section 3 you learned that using balanced chemical equations and the mole concept enabled you to solve stoichiometric problems. This helped you to predict quantities of reactants and products in chemical reactions. You performed an investigation to help validate the stoichiometric method.

Appendix



Glossary

Suggested Answers

Glossary

benefits: factors that are helpful or promote well-being

biomagnification: a process where a non-excretal substance increases in concentration as it is passed up the food chain

concentrated: having a greater amount of dissolved solute

diluted: having a lesser amount of dissolved solute

dynamic equilibrium: a steady state that occurs in a closed system when two opposite changes happen at the same rate

electrolyte: a solute that dissolves to form a conductive solution

heterogeneous mixtures: combinations of substances that have layers or separations

homogeneous mixtures: combinations of substances that produce a uniform appearance

indicators: dyes that change colour depending on the acidity of the solution

insoluble: incapable of being dissolved completely

molar mass: the number of grams of a substance needed to make one mole; symbolized by *M*

neutralization reaction: chemical change involving an acid and base forming an ionic compound and water

non-electrolyte: a solute that does not form a conducting solution when it dissolves

precipitate: a solid formed when two aqueous solutions react

products: substances that are the result of a chemical reaction
The products are on the right side of the arrow in a balanced chemical equation.

qualitative analysis: any method used to determine the identity of a substance

quantitative analysis: a method used to determine how much of substance is in a sample

reactants: substances that interact to break and reform bonds in the preparation of new chemical substances
The reactants are on the left side of the arrow in a balanced chemical equation.

risks: dangerous elements or factors

saturated solution: a solution that can dissolve no more solute at a given temperature

solubility: how well a substance dissolves

solubility table: a chart used to predict whether an ionic compound is soluble or insoluble

soluble: capable of being dissolved

solute: the substance in a solution present in the least amount

solvent: the substance in a solution present in the greatest amount

theoretical yield: the calculated mass of a product

toxic: poisonous or harmful to living organisms

Suggested Answers

Section 1: Activity 1

1. • latex paint • cup of tea • bread
   • pop • tap water

2. Latex paint appears uniform unless it is allowed to settle. Tea and tap water appear uniform; so some people do not think that they are mixtures.

3. A solution is a homogeneous mixture that does not have separate parts to it.

4. A solution can be in any state. For example, a solid dissolved in a solid, a gas dissolved in a liquid, and so on.

5. An aqueous solution is a homogeneous mixture in which water is the solvent.

6.

Solution	Solute	Solvent
antifreeze	ethylene glycol	water
solder	tin	lead
pop	carbon dioxide	water

Note: Solutions like antifreeze and solder can have varying amounts of each part, making it difficult to know which is the solute and which is the solvent. The answers given here follow what is given in *Visions* 2.

7. The following are a number of possible answers. Other examples may be acceptable.

Examples in Living Systems

- blood plasma
- saliva
- lymph
- cytoplasm
- soil nutrients
- oxygen dissolved in water

Examples in Non-living Systems

- detergent
- batteries
- fertilizers
- bread
- acids
- bases

8. Answers can include any of the following:

- pesticides
- carbon
- nitrates
- tetrachloride
- benzene
- chloroform
- toluene
- gasoline

9. Health and Welfare Canada sets standards for drinking water.

10. **W**orkplace **H**azardous **M**aterials **I**nformation **S**ystem

11. The symbols B, C, D-1, D-2, E, and F could apply to aqueous solutions.

12. A Material Safety Data Sheet is sent with the chemical to make sure that it is handled and stored properly.

13. When working with a chemical, you need to read the label to find information on risks, safety precautions, and first aid. The Material Safety Data Sheet contains information that is more detailed regarding product identification, physical properties, and hazard data.

Section 1: Activity 2

1.
- table salt (✓)
- cooking oil
- baking soda (✓)
- sand
- laundry soap (✓)
- steel wool
- headache tablet (✓)
- table sugar (✓)

2. The two types of compounds that dissolve easily in water are ionic and molecular.

3. Each of these compounds form ions when they first dissolve. $NaI_{(s)}$ forms $Na^{+}_{(aq)}$ and $I^{-}_{(aq)}$ and $Pb(NO_3)_{2(s)}$ forms $Pb^{2+}_{(aq)}$ and $NO_3^{-}{}_{(aq)}$.

4. Water is a polar molecule with a positive and negative end; thus, water attracts the positive sodium ion and the negative iodide ion from the crystal.

5. The polar water molecule has charged ends that are attracted to oppositely charged parts of the crystal. The crystal is attracted to the water molecule too. When the crystal starts to break apart, the water molecules squeeze into the crystal making it even more unstable.

6. Molecular compounds dissolve in water if they are polar. The positive part of the molecule is attracted to the negative part of the water molecule. The negative part of the molecule is attracted to the positive part of the water molecule. The water molecules squeeze between the molecules because of the water's attraction to different parts of the molecules.

7.

Similarities	Differences
• Water molecules move in and break things apart. • Sections of compounds have a positive and negative end • All things at the beginning of the dissolving process are still present at the end.	• In the ionic compound the molecule separates into two ions, while in the molecular compound the molecules stay the same but move apart when water molecules squeeze in between.

8. Nonpolar molecules form layers because they do not have any positive or negative parts to attract polar water molecules.

9. You need to know whether substances are ionic, polar, or nonpolar to predict if they will dissolve.

10. You might find a dessicant pouch in your camera case. A desiccant is used in a camera case to keep excessive moisture from building up and possibly causing damage to the camera or film. Bottles of vitamins often have dessicant packages in them.

11. The sweetest cup of tea is the most concentrated in terms of sugar.

12. You can see that the sugar has disappeared or has returned to the bottom of the cup, but you cannot actually see the sugar going into solution.

13. The saturated solution is continuously dissolving and recrystallizing.

14. The rate of dissolving in a saturated solution is balanced by the rate of recrystallizing.

15. You cannot see any differences in the dissolving and recrystallizing because they are happening on a molecular level.

16. Solution A is $Na_2CrO_{4(aq)}$ because it contains $CrO_4^{2-}{}_{(aq)}$ which is yellow. Solution B is $KMnO_{4(aq)}$ because it contains $MnO_4^{-}{}_{(aq)}$ which is purple.

17. Solution A is $Co(NO_3)_{2(aq)}$ because the $Co^{2+}{}_{(aq)}$ ions are pink. Solution B is $NaNO_{3(aq)}$. Since neither ion has a colour stated on the chart, you can assume they are colourless. Solution C is $Cr(NO_3)_{2(aq)}$ because the $Cr^{2+}{}_{(aq)}$ ions are blue.

18.

Name	Formula	High or Low Solubility
sodium nitrate	$NaNO_{3(s)}$	high
barium chloride	$BaCl_{2(s)}$	high
lead (II) hydroxide	$Pb(OH)_{2(s)}$	low
ammonium phosphate	$(NH_4)_3PO_{4(s)}$	high
barium sulphide	$BaS_{(s)}$	high
calcium carbonate	$CaCO_{3(s)}$	low

19. The four ways are as follows:

- observing the colour and checking on a chart of ion colours
- using colour indicators such as litmus paper
- flame test observation
- colour of precipitate

20. The (s) after the compound indicates which are precipitates.

$$Ca(CH_3COO)_{2(aq)} + (NH_4)_2CO_{3(aq)} \rightarrow CaCO_{3(s)} + 2NH_4CH_3COO_{(aq)}$$

$$Ca(CH_3COO)_{2(aq)} + (NH_4)_2SO_{4(aq)} \rightarrow CaSO_{4(s)} + 2NH_4CH_3COO_{(aq)}$$

$$Ca(CH_3COO)_{2(aq)} + 2NH_4OH_{(aq)} \rightarrow Ca(OH)_{2(s)} + 2NH_4CH_3COO_{(aq)}$$

$$Mg(CH_3COO)_{2(aq)} + (NH_4)_2CO_{3(aq)} \rightarrow MgCO_{3(s)} + 2NH_4CH_3COO_{(aq)}$$

$$Mg(CH_3COO)_{2(aq)} + (NH_4)_2SO_{4(aq)} \rightarrow MgSO_{4(aq)} + 2NH_4CH_3COO_{(aq)}$$

$$Mg(CH_3COO)_{2(aq)} + 2NH_4OH_{(aq)} \rightarrow Mg(OH)_{2(s)} + 2NH_4CH_3COO_{(aq)}$$

$$Sr(CH_3COO)_{2(aq)} + (NH_4)_2CO_{3(aq)} \rightarrow SrCO_{3(s)} + 2NH_4CH_3COO_{(aq)}$$

$$Sr(CH_3COO)_{2(aq)} + (NH_4)_2SO_{4(aq)} \rightarrow SrSO_{4(s)} + 2NH_4CH_3COO_{(aq)}$$

$$Sr(CH_3COO)_{2(aq)} + 2NH_4OH_{(aq)} \rightarrow Sr(OH)_{2(aq)} + 2NH_4CH_3COO_{(aq)}$$

21.

	$Ca(CH_3COO)_{2(aq)}$	$Mg(CH_3COO)_{2(aq)}$	$Sr(CH_3COO)_{2(aq)}$
$(NH_4)_2CO_{3(aq)}$	✓	✓	✓
$(NH_4)_2SO_{4(aq)}$	✓		✓
$NH_4OH_{(aq)}$	✓	✓	

22. **Textbook question 1:** All compounds that formed with the carbonate ions are insoluble and form precipitates. All the ammonium and acetate compounds are soluble.

Textbook question 2: You could identify the contents by adding ammonium sulphate. If it is calcium acetate, a precipitate will form. If it is magnesium acetate, no solid will appear.

Textbook question 3: Strontium acetate and strontium hydroxide both dissolve well in water. Therefore, you would have to dissolve and react them with another solution. If you added magnesium acetate, then only the strontium hydroxide solution will react to form a precipitate, $Mg(OH)_{2(s)}$.

Textbook question 4: Add a compound like ammonium carbonate or ammonium hydroxide. The magnesium ions should form a precipitate. This is not a sure test since other metallic ions could give a precipitation result.

Textbook question 5: You can separate ions by making only one form a precipitate. You could react the solution with ammonium hydroxide. This would make the calcium ions precipitate. The strontium would not precipitate. Then you could filter out the calcium hydroxide precipitate.

23. Refer to the answers to question 22 of Section 1, Activity 2.

Section 1: Activity 3

1. Table salt is an ionic compound, and table sugar is a molecular compound.

2.

Substance	Conductivity
distilled water	no
sugar solution	no
salt solution	yes
tap water	yes

3. The results were not identical. The distilled water did not conduct electricity while the tap water did. This is because tap water is not pure; it is a solution containing gases and ions.

4. Aqueous solutions that conduct must have ions in them. This means that ionic solutes will form conducting solutions. (If the ionic solute is soluble in water, the solution is a good conductor; if the ionic solute is of low solubility, the solution is a poor conductor.)

5. $Na^{+}_{(aq)}$ and $Cl^{-}_{(aq)}$ are the ions in an aqueous table salt solution.

6. The formula indicates pure sodium chloride is solid and does not have a charge associated with it. The formula for the ions indicates they are in an aqueous solution and have a positive or negative charge.

7. Places where electrolytes are present include the following:

   - tap water
   - battery acid
   - juices
   - blood plasma
   - cleaning solutions
   - and so on

8. Ionic compounds of low solubility would make the light glow faintly.

9.

Solution	Conductivity	Red Litmus Test	Blue Litmus Test	Reacted With $Mg_{(s)}$ to Produce Bubbles
salt solution	yes	red	blue	no
sugar solution	no	red	blue	no
baking soda	yes	blue	blue	no
vinegar	yes	red	red	yes

10. The vinegar is an acid; the baking soda is a base; and the salt and sugar solutions are neither acidic nor basic.

11. The litmus papers do not change colour in a neutral solution.

12. You must use both the red and the blue litmus papers to test a neutral solution. You need to see if the colour is due to a change or if it is just staying the same. For example, if red litmus remains red, it means that the solution is either neutral or acidic. You need to confirm this with blue litmus paper to determine whether the solution is neutral or acidic.

13. Ionic or molecular compounds can form neutral solutions.

14. The acid is the only substance that turns blue litmus paper red, and the only one to react with the magnesium metal to produce a gas.

15.

	Name	Some of Its Uses	General Properties
Base	• lime	• fertilizer • precipitate sewage • dump into rivers to reduce acidity • dump into coal-burning power plants to neutralize acidic pollutants	• turns litmus blue • does not react with metals • does not make limestone bubble • reacts with acids
Acid	• sulphuric acid • citric or acetic acid	• battery acid • catalyst in reactions • present in fruits or vinegar	• turns litmus red • reacts with metals to form hydrogen gas • reacts with limestone to form $CO_{2(g)}$ • reacts with bases

16.

Reaction	Reactants	Observations
1	ammonia and hydrogen chloride	a solid forms where the two gases meet
2	sodium hydroxide and nitric acid	no visible reaction occurred
3	acetic acid and sodium bicarbonate	bubbles appeared

17. The bubbles were caused by the formation and release of CO_2 gas.

18. The process that occurs is called neutralization. You are taking a base (the antacid) to calm the effects of excess acid in your stomach.

19. a. $HF_{(aq)} + NaOH_{(aq)} \rightarrow NaF_{(aq)} + HOH_{(l)}$

b. $H_2SO_{4(aq)} + 2KOH_{(aq)} \rightarrow K_2SO_{4(aq)} + 2HOH_{(l)}$

c. $CH_3COOH_{(aq)} + NaOH_{(aq)} \rightarrow NaCH_3COO_{(aq)} + HOH_{(l)}$

d. $Ba(OH)_{2(aq)} + 2HNO_{3(aq)} \rightarrow Ba(NO_3)_{2(aq)} + 2HOH_{(l)}$

20.

Property	Class of Solution
conductive solution	acid, base, neutral ionic
tastes sour	acid
reacts with metals to form hydrogen gas	acid
causes a change in litmus paper	acid, base
participates in neutralization reactions	acid, base

21. $H^+_{(aq)}$ (hydrogen ion) is responsible for acidic properties.

22. $OH^-_{(aq)}$ (hydroxide ion) is the ion responsible for the properties of a base.

23. A neutralization reaction is a chemical change where an acid reacts with a base to form an ionic compound and water.

24. You should have predicted each of the solutions to be either acidic, basic, or neutral.

25.

Solution	Reacts with $Mg_{(s)}$?	Lighted Splint Test	Red Litmus	Blue Litmus	Conductive or Nonconductive
vinegar	yes	yes	red	red	conductive
table salt	no	no	red	blue	conductive
rain water	yes	yes	red	red	conductive
quicklime	no	no	blue	blue	conductive
sugar	no	no	red	blue	nonconductive
carbonated water	yes	yes	red	red	conductive
baking soda	no	no	blue	blue	conductive
magnesia	no	no	blue	blue	conductive
lye	no	no	blue	blue	conductive

26. The acids are vinegar, rainwater, and carbonated water. The bases are quicklime, baking soda, magnesia, and lye. The neutral solutions are table salt and sugar.

27. **Textbook question 1:** $Mg_{(s)}$ was added to the solutions to see if it would react and form $H_{2(g)}$.

Textbook question 2: When magnesium was added to the vinegar, rainwater, and carbonated water, bubbling occurred and a gas formed. This is evidence that a reaction happened.

Textbook question 3: The gas was hydrogen because it popped when tested with the lit splint. This shows that the solution contained an acid since hydrogen gas was released.

Textbook question 4: Answers may vary depending on the basis of your predictions. For example, you may have predicted that the rainwater was neutral because of the formula $SO_{3(aq)}$. According to the test, it is acidic. You may have also predicted that baking soda was neutral if you looked at the chemical formula. It does not contain hydrogen ions or hydroxide ions. It is basic according to the tests.

Textbook question 5: The metal oxides formed basic solutions. For example, $MgO_{(aq)}$ is a metal oxide and so is $CaO_{(aq)}$ (quicklime).

28. Sample results are given in the following chart.

Trial Number	Drops of Base	Drops of Acid
1	19	10
2	21	11
3	20	10

Note: Your answer depends on the size of the drops your eye dropper produces.

29. An equal volume of 0.1 mol/L hydrochloric acid is required to neutralize a given volume of 0.1 mol/L sodium hydroxide.

30. **Textbook question 1:** As you add the base, the acidity decreases. You can see this when the base is added and you mix it – the pink colour appears.

Textbook question 2: As you add the acid, the alkalinity decreases. You can see this when the acid is added and you mix it – the pink colour disappears.

Textbook question 3: $HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + HOH_{(l)}$

The products of the reaction are sodium chloride and water.

31. You should have predicted each solution to be either an acid, a base, or a neutral solution.

32.

Solution	Conducts Electricity?	Red Litmus	Blue Litmus	Bubbles Released When $Mg_{(s)}$ Is Added
$HCl_{(aq)}$	yes	red	red	yes
$NaOH_{(aq)}$	yes	blue	blue	no
household ammonia	yes	blue	blue	no
distilled water	no	red	blue	no
vinegar	yes	red	red	yes
baking soda	yes	blue	blue	no
laundry soap	yes	blue	blue	no
sugar solution	no	red	blue	no
table salt solution	yes	red	blue	no

33. The acids are $HCl_{(aq)}$ and vinegar. The bases are $NaOH_{(aq)}$, household ammonia, baking soda, and laundry soap. The neutral substances are distilled water, sugar solution, and table salt solution.

34. Hydrogen gas is being released.

35. The following chart shows sample results for three trials.

Trial	Number of Drops Needed to Change Indicator Green
1	22
2	20
3	19

36. $HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + HOH_{(l)}$

37. OH^-

38. A salt is an ionic compound.

39. Your report should be similar to the following.

Purpose

The purpose of this investigation is to make and evaluate an acid-base indicator.

Materials

- pot
- grater, food processor, or knife
- baking soda
- four substances to be tested
- purple cabbage
- water
- vinegar

Procedure

Step 1: Prepare the indicator according to the recipe, and allow it to cool.

Step 2: Test the indicator solution with baking soda to determine the basic colour.

Step 3: Test the indicator solution with vinegar to determine the acidic colour.

Step 4: Test the four substances with the indicator.

Step 5: Make a chart to record your results.

Observations

The following is a sample chart. Answers may vary depending on the solutions you picked.

THE COLOUR OF PURPLE CABBAGE INDICATOR IN VARIOUS SOLUTIONS	
Solution	**Colour of Indicator**
water	purple
baking soda	blue-green
lemon juice	red

Analysis and Interpretation

Acids will be red; bases will be blue; and neutral (or nearly neutral) solutions will be purple.

Your evaluation of the indicator will vary but may have been similar to the following. The purple cabbage indicator worked well for deciding which solutions were acids and which were bases. The differences between acids or bases and neutral solutions were more difficult to see as the colour difference was not that great.

Section 1: Follow-up Activities

Extra Help

1.

Solution	Qualitative Test	Observation	Classification or Identity
A	colour of solution	purple	contains permanganate ions
B	mixed with $NaCH_3COOH_{(aq)}$	white precipitate forms	contains either silver or mercury(I) ions
C	conductivity meter	light glows	contains ions, the solute may be ionic, acidic, or basic
D	red litmus blue litmus	turns blue stays blue	contains a base
E	magnesium	bubbles	contains an acid

2. a. $AgNO_{3(aq)} + NaCl_{(aq)} \rightarrow AgCl_{(s)} + NaNO_{3(aq)}$ (precipitation)

   b. $NaOH_{(aq)} + HBr_{(aq)} \rightarrow NaBr_{(aq)} + HOH_{(l)}$ (neutralization)

   c. $CaCl_{2(aq)} + K_2SO_{4(aq)} \rightarrow CaSO_{4(s)} + 2KCl_{(aq)}$ (precipitation)

   d. $KOH_{(aq)} + HNO_{3(aq)} \rightarrow KNO_{3(aq)} + HOH_{(l)}$ (neutralization)

3.

Solution	Component	Amount	Solute or Solvent?
Tooth Filling	mercury	50%	solvent
	silver	35%	solute
	tin	15%	solute
Air	argon	0.93%	solute
	carbon dioxide	0.03%	solute
	oxygen	20.9%	solute
	nitrogen	78.1%	solvent
	others	0.04%	solute

Steel	tungsten	8%	solute
	nickel	14%	solute
	iron	51%	solvent
	chromium	24%	solute
	copper	3%	solute

4. By looking at the formulas, you know the solutions are an acid, a base, or a neutral solution. $HNO_{3(aq)}$ is an acid because it contains hydrogen ions; $NaOH_{(aq)}$ is a base because it contains hydroxide ions; and $NaCl_{(aq)}$ is neutral because it contains neither hydrogen ions nor hydroxide ions. To tell which one is which you should use an indicator such as litmus or bromothymol blue. You should use both red and blue litmus to tell the difference between acidic, basic, and neutral solutions.

5. a. According to the table, the solution could contain chromium(III), copper(I), iron(II), or nickel(II) ions.

   b. If the solution forms a precipitate, then, according to the solubility table, it could only be copper(I) ions since only copper has a low solubility with chloride ions.

6. You cannot see any changes because they are happening at an atomic scale. The dissolved solute is crystallizing into a solid while the solid is dissolving.

7. Acidic substances found in the home include fruits, vinegar, vegetables, and so on.

   Basic substances include cleansers, baking soda, soaps, and so on.

8. a. Soluble ionic compounds and polar substances dissolve well in water.

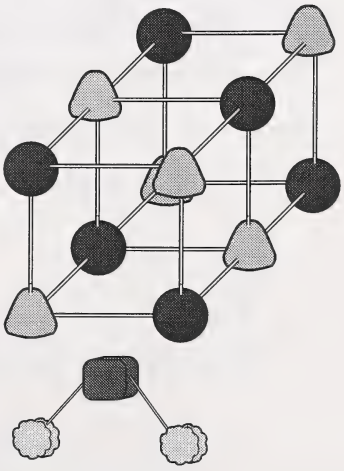
   b. Since water is polar with a positive and negative end to the molecule, it can separate ions or polar molecules from one another.

Enrichment

1. To create a model of a simple ionic crystal, take the jujubes and remove two of your favourite colours. One colour can represent the positive ion and the other colour can represent the negative ion. Using toothpicks, join six positives with six negatives in a box-like structure so that each colour is never connected to itself.

   To create a model of the incoming water molecule, pick two other colours. Use two jujubes of one colour and one jujube of another. Join these three jujubes with two toothpicks into a V-shaped molecule.

   Fly the water molecule into the crystal, separating the ions. Remove the toothpicks and eat the remains of the crystal.



2. a.

Day	Appearance of Crystals Before Mixing	Settling Time (min)	Day	Appearance of Crystals Before Mixing	Settling Time (min)
1	fine, colourless	17	8	same as day 7	16
2	fine, colourless	17	9	same as day 8	16
3	fine, colourless	17	10	look as if they are larger and fewer	14
4	fine, colourless	17	11	same as day 10	14
5	fine, colourless	17	12	same as day 11	14
6	look as if they are larger	17	13	same as day 12	12
7	same as day 6	16	14	crystals look larger	8

b. The crystals take less time to settle over fourteen days.

c. No, the crystals look as if they are getting bigger and fewer in number. So there are changes happening to the saturated solution over the course of the fourteen days.

d. The experiment shows that there is something going on in the saturated solution, but you must watch it over a long period of time to see the tiny changes. It is like watching erosion. You cannot see it happening in five minutes. The total amount of the substance does not change, but the number, size, and shape of the crystals do. This means that whatever is changing is balanced or happening at the same speed. This is equilibrium – the balance between two things that happen and cancel out each other.

3. Your report should include the following information. Sulphuric acid is produced using the following steps:

Step 1: Sulphur is burned to produce sulphur dioxide gas.

Step 2: The sulphur dioxide is then reacted with oxygen to produce sulphur trioxide gas.

Step 3: The sulphur trioxide gas reacts with water to form sulphuric acid.

The reactions can be summarized as follows:

$$S_{(l)} + O_{2(g)} \rightarrow SO_{2(g)}$$

$$SO_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow SO_{3(g)}$$

$$SO_{3(g)} + H_2O_{(l)} \rightarrow H_2SO_{4(l)}$$

Steam is used to melt the sulphur. The sulphur is burned and the $SO_{2(g)}$ is collected. At high temperatures (under 500°C), the sulphur dioxide is roasted to form $SO_{3(g)}$. The $SO_{3(g)}$ is not reacted with the water directly because then a hot acidic mist would be created. So in a place in the acid plant known as the converter, the $SO_{3(g)}$ is absorbed by concentrated sulphuric acid solution.

Sulphuric acid is one of the most widely used chemicals. It is used by many industries, but it is usually not a part of the final product. It is used in fertilizer manufacturing, petrochemical refining, metal production, paper production, and paint production. It can be used in manufacturing leather, tin plating, and dyeing cloth.

Section 2: Activity 1

1. A scientist might say the cup of coffee is dilute or it is coffee that has a low concentration.

2.

Method	Units	Used to Express	Example
percent by mass	$\frac{\text{g solute}}{\text{g solution}} \times 100$	concentration of a commercial product	numbers on the bags of fertilizer
percent by volume	$\frac{\text{mL solute}}{\text{mL solution}} \times 100$	concentration of a liquid dissolved in a liquid	suntan lotion
percent mass/volume	$\frac{\text{g solute}}{\text{mL solution}} \times 100$	concentration of a solid dissolved in a liquid	highly concentrated solutions
parts per million	$\frac{\text{g solute}}{\text{g solution}} \times 10^6$	very low concentrations	concentration of ions or pesticides in drinking water
moles per litre	$\frac{\text{mol solute}}{\text{L solution}}$	precise description of amount of solute present	concentration of an acid or base

3. You can use a variety of ways to describe the concentration, but the best way to describe concentration of a drop of dye in a pool is to use parts per million or parts per billion.

4. **Textbook question 1:**

$$\%\ \text{glucose by mass} = \frac{10.4\ \text{g glucose}}{10.4\ \text{g glucose} + 255\ \text{g water}} \times 100$$
$$= 3.92\%\ \text{(3 significant digits)}$$

Textbook question 3:

$$\%\ \text{potassium oxide} = \frac{19.5\ \text{g potassium oxide}}{65.0\ \text{g fertilizer}} \times 100$$
$$= 30.0\%\ \text{(3 significant digits)}$$

Note: This question asks for percent of potassium oxide and not percent by mass of potassium oxide.

Textbook question 4: 30.0% isopropyl alcohol means there would be 30.0 g of isopropyl alcohol in 100 g of solution. The mass of isopropyl alcohol in 66 g of solution is as follows:

$$\frac{30.0\text{ g isopropyl alcohol}}{100\text{ g solution}} \times 66\text{ g solution} = 20\text{ g (2 significant digits)}$$

5. **Textbook question 1:**

$$\text{ppm fluoride ion} = \frac{\text{mass fluoride ion}}{\text{mass solution}} \times 10^6$$
$$= \frac{0.000\,750\text{ g}}{600\text{ g}} \times 10^6$$
$$= 1.25\text{ ppm (3 significant digits)}$$

This is below 1.5 ppm given in the table on page 263 of *Visions 2*; thus, it is an acceptable level.

Textbook question 2:

$$\text{ppm sulphur dioxide} = \frac{\text{mass sulphur dioxide}}{\text{mass air}} \times 10^6$$
$$= \frac{0.013\text{ g}}{1500\text{ g}} \times 10^6$$
$$= 8.7\text{ ppm (2 significant digits)}$$

Textbook question 4:

$$34\text{ ppm} = \frac{34}{10^6} = \frac{\text{mass sodium ion}}{300\text{ g solution}}$$
$$\text{mass sodium ion} = \frac{34 \times 300\text{ g}}{10^6}$$
$$= 0.010\text{ g (2 significant digits)}$$

6. $C = \frac{n}{V}$
$= \frac{3.50\text{ mol}}{2.00\text{ L}}$
$= 1.75\text{ mol/L (3 significant digits)}$

7. $C = \frac{n}{V}$
$= \frac{0.700\text{ mol}}{1.5\text{ L}}$
$= 0.47\text{ mol/L (2 significant digits)}$

8. The solution with the concentration of 1.0 mol/L is alarming. The pesticide concentration is very high. It is much more concentrated than the solution expressed in ppm.

9. To change mL to L, you should multiply by $\frac{1\text{ L}}{1000\text{ mL}}$.

10. In the lab, you use a balance that measures mass in grams (g).

11. a. $\text{molar mass} = \left[(2\times 1.01)+32.06+(4\times 16.00)\right]\text{g/mol}$
$= 98.08\text{ g/mol}$

$$\text{number of moles} = 2.73\,\cancel{\text{g}}\times\frac{1\text{ mol}}{98.08\,\cancel{\text{g}}}$$
$$= 0.0278\text{ mol}\ \ (3\text{ significant digits})$$

b. $\text{molar mass} = (22.99+16.00+1.01)\text{ g/mol}$
$= 40.00\text{ g/mol}$

$$\text{number of moles} = 0.016\,\cancel{\text{g}}\times\frac{1\text{ mol}}{40.00\,\cancel{\text{g}}}$$
$$= 0.000\,40\text{ mol}\ \ (2\text{ significant digits})$$

c. $\text{molar mass} = \left[(2\times 14.01)+(8\times 1.01)+32.06+(4\times 16.00)\right]\text{g/mol}$
$= 132.16\text{ g/mol}$

$$\text{number of moles} = 15.0\,\cancel{\text{g}}\times\frac{1\text{ mol}}{132.16\,\cancel{\text{g}}}$$
$$= 0.113\text{ mol}\ \ (3\text{ significant digits})$$

12. a. $\text{molar mass} = \left[(2\times 14.01)+(8\times 1.01)+12.01+(3\times 16.00)\right]\text{g/mol}$
$= 96.11\text{ g/mol}$

$$\text{number of grams} = 0.317\,\cancel{\text{mol}}\times\frac{96.11\text{ g}}{1\,\cancel{\text{mol}}}$$
$$= 30.5\text{ g}\ \ (3\text{ significant digits})$$

b. $\text{molar mass} = \left[87.62+(4\times 12.01)+(6\times 1.01)+(4\times 16.00)\right]\text{g/mol}$
$= 205.72\text{ g/mol}$

$$\text{number of grams} = 0.086\,\cancel{\text{mol}}\times\frac{205.72\text{ g}}{1\,\cancel{\text{mol}}}$$
$$= 18\text{ g}\ \ (2\text{ significant digits})$$

13.

Measurement	Unit
volume	L
concentration	mol/L
amount	mol

14. **Textbook question 2:**

Unit Analysis Method

Convert grams to moles.

$$\text{molar mass} = (22.99 + 16.00 + 1.01)\ \text{g/mol}$$
$$= 40.00\ \text{g/mol}$$

$$3.05\ \text{g} \times \frac{1\ \text{mol}}{40.00\ \text{g}} = 0.076\ 250\ \text{mol}$$

Convert mL to L.

$$50.0\ \text{mL} \times \frac{1\ \text{L}}{1000\ \text{mL}} = 0.0500\ \text{L}$$

Calculate the concentration (mol/L).

$$\text{concentration} = 0.076\ 250\ \text{mol} \times \frac{1}{0.0500\ \text{L}}$$
$$= 1.53\ \text{mol/L}\ \text{(3 significant digits)}$$

Formula Method

data: $m = 3.05\ \text{g}$

$M = (22.99 + 16.00 + 1.01)$
$= 40.00\ \text{g/mol}$

$V = 50.0\ \text{mL}$
$= 0.0500\ \text{L}$

$n = ?$

$C = ?$

solution: $n = \frac{m}{M} = \frac{3.05\ \text{g}}{40.00\ \text{g/mol}}$
$= 0.076\ 250\ \text{mol}$

$C = \frac{n}{V} = \frac{0.076\ 250\ \text{mol}}{0.0500\ \text{L}}$
$= 1.53\ \text{mol/L}$
(3 significant digits)

The use of a calculator for the previous question is illustrated below. The order of the steps may be different for your calculator. Consult your manual for additional help.

	Function	Display
Enter	3.05	3.05
Press	÷	3.05
Press	(	(01 0.
Enter	22.99	22.99
Press	+	22.99
Enter	16.00	16.00
Press	+	38.99
Enter	1.01	1.01
Press	)	40.
Press	÷	0.07625
Press	(	(01 0.
Enter	50.0	50.0
Press	÷	50.
Enter	1000	1000.
Press	)	0.05
Press	=	1.525

Textbook question 4:

Unit Analysis Method

Convert grams to moles.

$$\text{molar mass} = [63.55 + 32.06 + (4 \times 16.00)]\ \text{g/mol}$$
$$= 159.61\ \text{g/mol}$$

$$1.84\ \text{g} \times \frac{1\ \text{mol}}{159.61\ \text{g}} = 0.011\,528\ \text{mol}$$

Convert mL to L.

$$500.0\ \text{mL} \times \frac{1\ \text{L}}{1000\ \text{mL}} = 0.5000\ \text{L}$$

Calculate the concentration (mol/L).

$$\text{concentration} = 0.011\,528\ \text{mol} \times \frac{1}{0.5000\ \text{L}}$$
$$= 0.0231\ \text{mol/L or } 2.31 \times 10^{-2}\ \text{mol/L}$$
(3 significant digits)

Formula Method

data: $m = 1.84\ \text{g}$

$M = [63.55 + 32.06 + (4 \times 16.00)]\ \text{g/mol}$
$= 159.61\ \text{g/mol}$

$V = 500.0\ \text{mL}$
$= 0.5000\ \text{L}$

$n = ?$

$C = ?$

solution: $n = \frac{m}{M} = \frac{1.84\ \text{g}}{159.61\ \text{g/mol}}$
$= 0.011\,528\ \text{mol}$

$$C = \frac{n}{V} = \frac{0.011\,528\ \text{mol}}{0.5000\ \text{L}}$$
$$= 0.0231\ \text{mol/L}$$
(3 significant digits)

Textbook question 6:

Unit Analysis Method

Convert mL to L.

$$500.0\ \text{mL} \times \frac{1\ \text{L}}{1000\ \text{mL}} = 0.5000\ \text{L}$$

Find the number of moles.

$$\frac{0.200\ \text{mol}}{1\ \text{L}} \times 0.5000\ \text{L} = 0.100\,00\ \text{mol}$$

Find the mass.

$$\text{molar mass} = 22.99 + 1.01 + 32.06 + (4 \times 16.00)$$
$$= 120.06\ \text{g/mol}$$

$$0.100\,00\ \text{mol} \times \frac{120.06\ \text{g}}{1\ \text{mol}} = 12.0\ \text{g}$$
(3 significant digits)

Formula Method

data: $C = 0.200\ \text{mol/L}$

$V = 500.0\ \text{mL}$
$= 0.500\ \text{L}$

$M = [22.99 + 1.01 + 32.06 + (4 \times 16.00)]\ \text{g/mol}$
$= 120.06\ \text{g/mol}$

$n = ?$

$m = ?$

solution: $n = CV$
$= 0.200\ \text{mol/L} \times 0.5000\ \text{L}$
$= 0.100\,00\ \text{mol}$

$m = nM$
$= 0.100\,00\ \text{mol} \times 120.06\ \text{g/mol}$
$= 12.0\ \text{g}$ (3 significant digits)

Note: It is the molar mass of $NaHSO_4$ that is required to prepare the solution of hydrogen sulphate ions.

Textbook question 8:

Unit Analysis Method

Calculate the number of moles.

$$\frac{0.0017 \text{ mol}}{1 \cancel{\text{L}}} \times 20 \cancel{\text{L}} = 0.034\,00 \text{ mol}$$

Convert moles to mass.

$$\text{molar mass} = [(2 \times 39.10) + 16.00] \text{ g/mol}$$
$$= 94.20 \text{ g/mol}$$

$$0.034\,00 \cancel{\text{mol}} \times \frac{94.20 \text{ g}}{1 \cancel{\text{mol}}} = 3.2 \text{ g} \quad (2 \text{ significant digits})$$

Formula Method

data: $C = 0.0017 \text{ mol/L}$

$V = 20 \text{ L}$

$M = [(2 \times 39.10) + 16.00] \text{ g/mol}$

$= 94.20 \text{ g/mol}$

$n = ?$

$m = ?$

solution: $n = CV$

$= 0.0017 \text{ mol/L} \times 20 \text{ L}$

$= 0.034\,00 \text{ mol}$

$m = nM$

$= 0.034\,00 \text{ mol} \times 94.20 \text{ g/mol}$

$= 3.2 \text{ g} \quad (2 \text{ significant digits})$

Textbook question 12:

Unit Analysis Method

Convert grams to moles.

$$\text{molar mass} = (22.99 + 16.00 + 1.01) \text{ g/mol}$$
$$= 40.00 \text{ g/mol}$$

$$59 \cancel{\text{g}} \times \frac{1 \text{ mol}}{40.00 \cancel{\text{g}}} = 1.475 \text{ mol}$$

Calculate the volume.

$$1.475 \cancel{\text{mol}} \times \frac{1 \text{ L}}{19.4 \cancel{\text{mol}}} = 0.076\,03 \text{ L}$$

Convert L to mL.

$$0.076\,03 \cancel{\text{L}} \times \frac{1000 \text{ mL}}{1 \cancel{\text{L}}} = 76 \text{ mL} \quad (2 \text{ significant digits})$$

Formula Method

data: $C = 19.4 \text{ mol/L}$

$m = 59 \text{ g}$

$M = (22.99 + 16.00 + 1.01) \text{ g/mol}$

$= 40.00 \text{ g/mol}$

$n = ?$

$V = ?$

solution: $n = \frac{m}{M}$

$= \frac{59 \text{ g}}{40.00 \text{ g/mol}}$

$= 1.475 \text{ mol}$

$V = \frac{n}{C}$

$= \frac{1.475 \text{ mol}}{19.4 \text{ mol/L}}$

$= 0.076\,03 \text{ L}$

$= 76 \text{ mL} \quad (2 \text{ significant digits})$

Textbook question 13:

Unit Analysis Method

Convert mass to moles.

$$\text{molar mass} = (1.01 + 35.45)\ \text{g/mol}$$
$$= 36.46\ \text{g/mol}$$

$$5.0\ \text{g} \times \frac{1\ \text{mol}}{36.46\ \text{g}} = 0.1371\ \text{mol}$$

Calculate the volume.

$$0.1371\ \text{mol} \times \frac{1\ \text{L}}{8.0 \times 10^{-2}\ \text{mol}} = 1.7\ \text{L}\ \ (2\ \text{significant digits})$$

Formula Method

data: $C = 8.0 \times 10^{-2}\ \text{mol/L}$
$m = 5.0\ \text{g}$
$M = (1.01 + 35.45)\ \text{g/mol}$
$= 36.46\ \text{g/mol}$
$n = ?$
$V = ?$

solution: $n = \dfrac{m}{M}$

$$= \frac{5.0\ \text{g}}{36.46\ \text{g/mol}}$$
$$= 0.1371\ \text{mol}$$

$$V = \frac{n}{C}$$
$$= \frac{0.1371\ \text{mol}}{8.0 \times 10^{-2}\ \text{mol/L}}$$
$$= 1.7\ \text{L}\ \ (2\ \text{significant digits})$$

Section 2: Activity 2

1. Some answers you may have are as follows:

Good Reasons for Following a Recipe Exactly	Good Reasons for Changing a Recipe Here and There
• The product will turn out exactly as it is designed.	• If you don't like or can't eat an ingredient, you can change it.
• It is easier to follow a recipe.	• You can be creative while you cook.
• You can double or triple the recipe and still have the same product.	• If you don't have an ingredient, you can use other ones instead.
• It can be repeated the same way over and over again.	• You can create something that you can call your own.
• You don't need to memorize it.	• You don't waste time measuring exactly.

2. Solutions that may be included are as follows:

- liquid plant fertilizers
- household cleaning solutions and detergents
- vinegar
- frozen juices

3. No, the actual amount is the same. There is just more water mixed into it.

4. The solution that is most concentrated is C_1. This is always the case.

5. V_2 always has the greater volume.

6. To determine the amount of water needed, find the difference between the final volume and the initial volume $(V_2 - V_1)$. It is important that the final volume be V_2, not the sum of V_1 and V_2.

7. **Textbook question 1:**

data: $C_1 = 14.7 \text{ mol/L}$
$C_2 = 0.75 \text{ mol/L}$
$V_2 = 100.0 \text{ mL}$
$= 0.1000 \text{ L}$
$V_1 = ?$

solution:
$$C_1V_1 = C_2V_2$$
$$14.7 \text{ mol/L} \times V_1 = 0.75 \text{ mol/L} \times 0.1000 \text{ L}$$
$$V_1 = \frac{0.75 \text{ mol/L} \times 0.1000 \text{ L}}{14.7 \text{ mol/L}}$$
$$= 0.0051 \text{ L or } 5.1 \text{ mL} \quad (2 \text{ significant digits})$$

Textbook question 2:

data: $C_1 = 6.0 \text{ mol/L}$
$C_2 = 0.725 \text{ mol/L}$
$V_2 = 25 \text{ L}$
$V_1 = ?$

solution:
$$C_1V_1 = C_2V_2$$
$$6.0 \text{ mol/L} \times V_1 = 0.725 \text{ mol/L} \times 25 \text{ L}$$
$$V_1 = \frac{0.725 \text{ mol/L} \times 25 \text{ L}}{6.0 \text{ mol/L}}$$
$$= 3.0 \text{ L} \quad (2 \text{ significant digits})$$

Textbook question 3:

data: $C_1 = 12.5 \text{ mol/L}$
$C_2 = 0.100 \text{ mol/L}$
$V_2 = 250.0 \text{ mL}$
$= 0.2500 \text{ L}$
$V_1 = ?$

solution:
$$C_1V_1 = C_2V_2$$
$$12.5 \text{ mol/L} \times V_1 = 0.100 \text{ mol/L} \times 0.2500 \text{ L}$$
$$V_1 = \frac{0.100 \text{ mol/L} \times 0.2500 \text{ L}}{12.5 \text{ mol/L}}$$
$$= 0.002\,00 \text{ L or } 2.00 \text{ mL} \quad (3 \text{ significant digits})$$

Textbook question 4:

data: $C_1 = 6.0 \text{ mol/L}$
$V_1 = 1000 \text{ mL}$
$= 1.000 \text{ L}$
$V_2 = 8.0 \text{ L}$
$C_2 = ?$

solution:
$$C_1V_1 = C_2V_2$$
$$6.0 \text{ mol/L} \times 1.000 \text{ L} = C_2 \times 8.0 \text{ L}$$
$$C_2 = \frac{6.0 \text{ mol/L} \times 1.000 \text{ L}}{8.0 \text{ L}}$$
$$= 0.75 \text{ mol/L} \quad (2 \text{ significant digits})$$

8. The solution is made in a volumetric flask or a graduated cylinder. Volumetric flasks are more appropriate for making solutions but are not always available.

9. You dissolve the solution in a beaker first to make sure that all of the solid has dissolved. If you add solid into a volumentric flask, some will stick to the sides of the neck and will be difficult to wash down into the solution.

10. You rinse the beaker three times with distilled water into the flask so that all of solution is transferred.

11. Ideally, there should be no difference between the standard and the copper(II) sulphate solution you prepared. If there is, it would be in colour intensity.

12. Using a pH meter, the pH value of the solution should be 1.0. However, it is very unlikely that you will get exactly 1.0. A range of 0.7 to 1.8 is accurate enough depending on the accuracy of the concentration of the initial solution. With pH paper you will only be able to determine the pH to a value of 1 or 2 depending on the pH chart you have for comparison.

13. **Unit Analysis Method**

Convert mL to L.

$$100 \cancel{\text{mL}} \times \frac{1\ \text{L}}{1000\ \cancel{\text{mL}}} = 0.100\ \text{L}$$

Calculate the number of moles.

$$\frac{0.100\ \text{mol}}{1\ \cancel{\text{L}}} \times 0.100\ \cancel{\text{L}} = 0.010\ 000\ \text{mol}$$

Convert moles to mass.

$$\text{molar mass} = 63.55 + 32.06 + (4 \times 16.00) + (5 \times 18.02)$$
$$= 249.71\ \text{g/mol}$$

$$\frac{249.71\ \text{g}}{1\ \cancel{\text{mol}}} \times 0.010\ 000\ \cancel{\text{mol}} = 2.50\ \text{g}\ \text{(3 significant digits)}$$

Formula Method

data: $C = 0.100\ \text{mol/L}$
$V = 100\ \text{mL}$
$= 0.100\ \text{L}$
$M = 63.55 + 32.06 + (4 \times 16.00) + (5 \times 18.02)$
$= 249.71\ \text{g/mol}$
$n = ?$
$m = ?$

solution: $n = CV$
$= 0.100\ \text{mol/L} \times 0.100\ \text{L}$
$= 0.010\ 000\ \text{mol}$

$m = nM$
$= 0.010\ 000\ \text{mol} \times 249.71\ \text{g/mol}$
$= 2.50\ \text{g}\ \text{(3 significant digits)}$

14. data: $C_1 = 3.0\ \text{mol/L}$
$C_2 = 0.10\ \text{mol/L}$
$V_2 = 100\ \text{mL}$
$= 0.100\ \text{L}$
$V_1 = ?$

solution: $C_1V_1 = C_2V_2$
$3.0\ \text{mol/L} \times V_1 = 0.100\ \text{mol/L} \times 0.100\ \text{L}$
$V_1 = \dfrac{0.100\ \text{mol/L} \times 0.100\ \text{L}}{3.0\ \text{mol/L}}$
$= 0.0033\ \text{L or } 3.3\ \text{mL}\ \text{(2 significant digits)}$

15. According to the table on page 549 of *Visions 2*, the 0.100 mol/L acid solution should have a pH of 1.0.

16. When producing the copper(II) sulphate solution, a common mistake that is made is not rinsing all the solution into the volumetric flask. This means that the colour of the solution is less intense than it should be.

    An error could have been made in weighing the copper(II) sulphate pentahydrate.

    When making a more dilute solution with a graduated pipette, a common source of error is allowing all of the contents to flow into the volumetric flask. This means that too much of the concentrated solution is there and the resulting solution will have a higher concentration than expected.

17. Ideally, there should be no difference between the standard and the copper(II) sulphate solution you prepared. If there is, it would be in colour intensity.

18. The colour of the dilute solution is less intense than the concentrated one.

19. Refer to the answer to question 13 of Section 2, Activity 2.

20. data: $C_1 = 0.100\ \text{mol/L}$
    $C_2 = 0.0200\ \text{mol/L}$
    $V_2 = 100\ \text{mL} = 0.100\ \text{L}$
    $V_1 = ?$

    solution:
    $$C_1V_1 = C_2V_2$$
    $$0.100\ \text{mol/L} \times V_1 = 0.0200\ \text{mol/L} \times 0.100\ \text{L}$$
    $$V_1 = \frac{0.0200\ \text{mol/L} \times 0.100\ \text{L}}{0.100\ \text{mol/L}}$$
    $$= 0.0200\ \text{L or } 20.0\ \text{mL} \quad (3 \text{ significant digits})$$

21. The colour remains blue. The difference is in the intensity. The colour of the dilute solution is less intense than the colour of the concentrated one because there are fewer ions in the diluted solution.

22. Check your answer with the answer to question 16 of Section 2, Activity 2.

Section 2: Activity 3

1. The teacher suggested that risks be compared by the number of deaths resulting from the activities. This comparison is less than complete because it does not take into account the number of people involved in the activity and other factors.

2. Risks were compared by using the number of deaths per year in Canada.

3. They based their estimates on the most dramatic personal recollection of past experiences.

4. People's perception of risk, and the degree of emotional impact that a particular risk has, sometimes override numerical calculations based on best estimates or statistical analysis of data.

5. Risk = probability of occurrence × consequences.

6. In addition to the level of risk, the benefits gained from an activity must be considered.

7. a. i. Recognition of the risks and benefits.
   ii. Measurement or estimation of their effects.
   iii. Comparisons with alternative courses of action.

   b. The method is called risk-benefit analysis.

8. Answers will vary. What you perceive as high risk activities usually involve activities that you are not familiar with or that are not common to your everyday activities.

9. Answers will vary. Most or all activities involve some degree of risk. You might think you are risk-free if you are at home asleep in your own bed. However, there are a number of occurrences which could result in injury or death. Some examples are lightening striking the house, an earthquake occurring, a robber breaking in, and so on. The risk of these occurrences, however, is quite low.

10. Answers will vary. If you said the items in Column 1 are higher risk activities, you are probably among the majority who perceive these items as being high risk. However, in actual deaths per year the items in Column 1 can be directly linked to only a few hundred deaths. The items in Column 2 on the other hand can be directly linked to a total of about 30 000 deaths in a year. Therefore, Column 2 contains the items that are of higher risk in terms of actual deaths.

11. a. The following chart gives the ranking in terms of actual deaths or best estimate per year and the ranking of other people who were surveyed. Compare your ranking to the rankings given here.

Activity or Item	Ranking Based on Actual Fatalities or Best Estimate	Ranking Based on People Surveyed
drinking alcoholic beverages	2	6
riding a bicycle	8	10
flying on commercial flights	11	9
using electric power in the home	5	11
fire fighting	10	7
handguns	4	1
hunting	9	8
motorcycles	6	5
motor vehicles	3	2
nuclear power	12	3
smoking	1	4
swimming	7	12

[1]

b. Answers will vary. In general, you may have listed similar activities or items as high risk as those surveyed.

c. Answers will vary. You may find a number of activities or items which you ranked completely opposite to the ranking based on actual or estimated fatalities.

d. Smoking is the most risky activity based on actual or estimated fatalities.

e. Answers will vary. Perhaps you based your perception on how many people you know that have died from lung cancer or various other smoking-related causes.

12. From the table, scuba diving has the highest risk based on deaths per year.

[1] Chart taken from *On the Perception, Estimation and Evaluation of Risk.* Reprinted with permission from Atomic Energy of Canada Ltd., 1983.

13. Scuba diving is now ranked eighth when based on deaths per 100 000.

14. The risk of playing football compared to the risk of flying a home-built aircraft is almost the same based on deaths per year.

15. $\frac{1000}{0.9} = 1111$

$= 1 \times 10^3$ (1 significant digit)

It is about 1000 times more risky to fly a home-built aircraft than it is to play football.

16. Answers will vary. Number of deaths based per 100 000 participants should give you a truer sense of what your chances are of dying if you participate in a particular activity. For example, the table indicates that if for one year 100 000 people were flying a home-built aircraft and 100 000 people were playing football, then 1000 people would die flying the home-built aircraft and one would die playing football.

17. According to the article, the bottled water contains 19 parts per billion of benzene. The article showed that between 1 in 10^5 and 1 in 10^7 people could contract cancer as a result of drinking this water everyday over their lifetime. The risk is very low.

18. Drinking water in general is healthy. It keeps your fluids at the correct concentration and is the medium for the reactions that take place in your body. The benefits of drinking bottled water is the taste and knowing what is present in the water.

19. The risk of drinking the bottled water is so low that you may conclude that you would drink the water anyway. There is no information given about the benefits of drinking the bottled water. However, if you are a person who has used and likes bottled water, you would probably conclude that the water is drinkable.

20.

Risks	Benefits
• suspected carcinogen	• fruit less susceptible to insects • greater availability of fruit • less expensive fruit since they are more available • higher quality of fruit • other pesticides may pose greater risks

There are more benefits than risks in this list. Since the nature of the risks are unknown, you may choose to use the pesticide.

21. Voluntary risk is a risk you can control such as driving a car. You decide whether you want to drive or not and can control the risks to some extent by not driving in bad weather or at excessive speeds. Involuntary risk is a risk you cannot control such as eating food that has been contaminated. Although you can choose which foods you eat, you must eat some food.

22. **Textbook question 2:** Answers will vary but should include some discussion on how scientists are getting better at determining the presence of small amounts of various chemicals in our food, water, and air. Although the presence of these chemicals in small quantities may not cause problems, it is predicted that large amounts could. Sometimes, however, the amounts predicted are beyond what can be accumulated with excessive use for a lifetime.

23. Answers will vary. The following are a number of points that could be included in each category.

ISSUE: SHOULD MERCURY BE USED IN DENTAL FILLINGS?		
Points Which Support Use of Hg	**Points Which Oppose Use of Hg**	**Interesting Points**
• U.S. Food and Drug Administration states fillings are safe. • Panel from two branches of National Institutes of Health said there is no solid evidence showing the amount of vapour causes any illness • Dietary mercury in tuna fish might be a bigger source.	• People absorb 3 to 17 µg (micrograms) of mercury per day from dental amalgam vapour. • U of Arizona study found two-thirds of mercury in urine of people who have fillings comes from these fillings. • There is a strong correlation between the number of fillings and the amount of mercury in the urine.	• U of Kentucky scientists found abnormally high levels of mercury in brains of autopsied Alzheimer's victims. • In Sweden, research showed peoples kidney function improves after fillings are removed.

24. a. Two-thirds of the mercury in the urine is caused by dental fillings.

b. Mercury vapour escapes by chewing, brushing your teeth, grinding your teeth, drilling by dentists, or by having the fillings break down due to their age.

c. According to the UN World Health Organization, **3 to 17 µg (micrograms)** of mercury is absorbed by people daily from dental fillings.

25. The Canadian Dental Health Association, the U.S. Food and Drug Administration, and the National Institute of Health have said that mercury dental fillings are safe.

26. The Universities of Arizona, Calgary, and Kentucky are researching the effects of mercury fillings.

27. The more fillings you have in your mouth, the greater the amount of mercury found in your body.

28. a. The risks of removing and replacing your fillings may include the following:

- The surgery of dental procedures may be dangerous.
- Removing the fillings means more vapour escapes.
- Removing the fillings may be painful.
- All the mercury may not be removed.
- Removing the filling would be expensive.
- Removing the fillings may not be necessary.
- Porcelain fillings need to be replaced more often.

b. Some benefits include the following:

- The amount of mercury in your body is decreased.
- Removing the fillings would give you peace of mind.
- Porcelain fillings would look nicer.

c. Answers may vary. Since there are seven risks and three benefits of removing the fillings, you may decide that fillings are not worth removing. If you decide, however, that the benefits of removing the fillings are more important, you may decide that removing the fillings is worth it.

29. Your answer will depend on which decision you make, as described in the answer to question 28.c. in Section 2, Activity 3. If you can back up your decision by reasons such as the ones given in question 28.c., then your decision is a sound one.

Section 2: Follow-up Activities

Extra Help

1. a. You would dissolve a solid since you are told you have solid calcium chloride. The (s) after the compound name shows that it is a solid.

b. **Unit Analysis Method**

Convert mL to L.

$$100 \cancel{\text{mL}} \times \frac{1\ \text{L}}{1000 \cancel{\text{mL}}} = 0.100\ \text{L}$$

Calculate the number of moles.

$$\frac{0.500\ \text{mol}}{1 \cancel{\text{L}}} \times 0.100 \cancel{\text{L}} = 0.050\,000\ \text{mol}$$

Convert moles to grams.

$$\text{molar mass} = [40.08 + (2 \times 35.45)]\ \text{g/mol}$$
$$= 110.98\ \text{g/mol}$$

$$\frac{110.98\ \text{g}}{1 \cancel{\text{mol}}} \times 0.050\,000 \cancel{\text{mol}} = 5.55\ \text{g}$$

(3 significant digits)

Formula Method

data: $C = 0.500\ \text{mol/L}$

$V = 100\ \text{mL}$

$= 0.100\ \text{L}$

$M = [40.08 + (2 \times 35.45)]\ \text{g/mol}$

$= 110.98\ \text{g/mol}$

$n = ?$

$m = ?$

solution: $n = CV$

$= 0.500\ \text{mol/L} \times 0.100\ \text{L}$

$= 0.050\,000\ \text{mol}$

$m = nM$

$= 0.050\,000\ \text{mol} \times 110.98\ \text{g/mol}$

$= 5.55\ \text{g}$ (3 significant digits)

c.

Flow Chart

Dissolve 5.55 g of $CaCl_{2(s)}$ in a beaker with about 50 mL of distilled water.

↓

Transfer the dissolved $CaCl_2$ to a volumetric flask.

↓

Rinse beaker, funnel, and stirring rod into flask.

↓

Fill flask to the calibrated mark.

↓

Insert the stopper and invert several times.

2. a. You should perform a dilution since you are given aqueous sodium hydroxide. The (aq) after the compound name shows it is an aqueous solution.

b. data: $C_1 = 3.0\ \text{mol/L}$
$C_2 = 0.20\ \text{mol/L}$
$V_2 = 250\ \text{mL}$
$= 0.250\ \text{L}$
$V_1 = ?$

solution: $C_1V_1 = C_2V_2$

$3.0\ \text{mol/L} \times V_1 = 0.20\ \text{mol/L} \times 0.250\ \text{L}$

$$V_1 = \frac{0.20\ \text{mol/L} \times 0.250\ \text{L}}{3.0\ \text{mol/L}}$$

$= 0.017\ \text{L}$ or $17\ \text{mL}$ (2 significant digits)

c.

Flow Chart

Add about 175 mL of distilled water to a 250 mL volumetric flask.

↓

Using a graduated pipette, transfer 17 mL of 3.0 mol/L $NaOH_{(aq)}$ to the volumetric flask.

↓

Fill to the calibration mark.

↓

Insert the stopper and invert several times.

3. Other units of concentration are % volume, % mass, ppm, ppb, % m/V.

4. a. 0.350 L
b. 1.050 kg
c. 2.50×10^3 mL (Scientific notation is used to show 3 significant digits.)
d. 2.05 kg

5. a. Some risks are as follows:

- people may be allergic to spray
- spray may be poisonous to people
- spray may be needed more than once to rid the house of beetles

b. Some benefits are as follows:

- home has no more carpet beetles
- carpet beetles that spoil food are removed
- carpet beetles that damage furniture are removed

c. There are about the same number of risks as benefits. However, if you have carpet beetles, you would want to get rid of them. You would probably wish to use the household pesticide.

Enrichment

1. Answers will vary. In your report you might include the following points.

   - the purpose of the project
   - why the project was started in that particular area
   - initial reaction of local government as well as residents
   - what will the project do for the area
   - what are the short-term and long-term effects
   - what research into consequences of the project was done

   Your risk and benefit list may include the following points.

   - short- and long-term risks and benefits
   - local risks and benefits
   - provincial, national, or global risks and benefits
   - include economic, environmental, and aesthetic considerations

2. a. Answers will vary depending on the type of juice. In this answer, the label indicated 26 g of sugar in 250 mL of juice.

Unit Analysis Method

Convert grams to moles.

$$\text{molar mass} = (12 \times 12.01) + (22 \times 1.01) + (11 \times 16.00)$$
$$= 342.34 \text{ g/mol}$$

$$26 \text{ g} \times \frac{1 \text{ mol}}{342.34 \text{ g}} = 0.075\,95 \text{ mol}$$

Convert mL to L.

$$250 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 0.250 \text{ L}$$

Calculate the concentration of $C_{12}H_{22}O_{11}$.

$$\text{concentration} = 0.075\,95 \text{ mol} \times \frac{1}{0.250 \text{ L}}$$
$$= 0.30 \text{ mol/L} \quad (2 \text{ significant digits})$$

Formula Method

data: $m = 26$ g

$M = (12 \times 12.01) + (22 \times 1.01) + (11 \times 16.00$

$= 342.34$ g/mol

$V = 250$ mL

$= 0.250$ L

$n = ?$

$C = ?$

solution: $n = \frac{m}{M}$

$$= \frac{26 \text{ g}}{342.34 \text{ g/mol}}$$
$$= 0.075\,95 \text{ mol}$$

$C = \frac{n}{V}$

$$= \frac{0.075\,95 \text{ mol}}{0.250 \text{ L}}$$
$= 0.30$ mol/L (2 significant digits

b. For this particular juice, the concentration of sugar is equivalent to that of a can of pop.

3. **Textbook question 14:**

$$\frac{\text{mass of arsenic}}{\text{mass of solution}} \times 10^6 = \text{ppm of arsenic}$$

$$\frac{0.0010\ \text{g}}{\text{mass of solution}} \times 10^6 = 0.015\ \text{ppm of arsenic}$$

$$\text{mass of solution} = \frac{0.0010\ \text{g} \times 10^6}{0.015\ \text{ppm}}$$

$$= 6.7 \times 10^4\ \text{g}$$

Convert mass of water to volume of water $(1\ \text{kg} = 1\ \text{L})$.

$$6.7 \times 10^4\ \text{g} \times \frac{1\ \text{L}}{10^3\ \text{g}} = 67\ \text{L}\ \ (2\ \text{significant digits})$$

4. a. The solute is the essential or the ionine, and the solvent is the ethyl alcohol.

b.
$$\%m = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100$$

$$= \frac{237.5\ \text{g}}{450\ \text{kg}} \times 100$$

$$= \frac{0.2375\ \text{kg}}{450\ \text{kg}} \times 100$$

$$= 0.0528\%\ \ (3\ \text{significant digits})$$

$$\text{ppm} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 10^6$$

$$= \frac{237.5\ \text{g}}{450\ \text{kg}} \times 10^6$$

$$= \frac{0.2375\ \text{kg}}{450\ \text{kg}} \times 10^6$$

$$= 528\ \text{ppm}\ \ (3\ \text{significant digits})$$

c. **Unit Analysis Method**

Convert grams to moles.

$$\text{molar mass} = (13 \times 12.01) + (20 \times 1.01) + 16.00$$

$$= 192.33\ \text{g/mol}$$

$$237.5\ \text{g} \times \frac{1\ \text{mol}}{192.33\ \text{g}} = 1.2348\ \text{mol}$$

Calculate the concentration of $C_{13}H_{20}O_{(s)}$.

$$\text{volume} = 450\ \text{L}\ (1\ \text{kg} = 1\ \text{L})$$

$$\text{concentration} = 1.2348\ \text{mol} \times \frac{1}{450\ \text{L}}$$

$$= 0.002\,74\ \text{mol/L}$$

$$= 2.74 \times 10^{-3}\ \text{mol/L}$$

$$(3\ \text{significant digits})$$

Formula Method

data: $m = 237.50\ \text{g}$

$$M = (13 \times 12.01) + (20 \times 1.01) + 16.00$$

$$= 192.33\ \text{g/mol}$$

$V = 450\ \text{L}\ (1\ \text{kg} = 1\ \text{L})$

$n = ?$

$C = ?$

solution: $n = \frac{m}{M}$

$$= \frac{237.5\ \text{g}}{192.33\ \text{g/mol}}$$

$$= 1.2348\ \text{mol}$$

$$C = \frac{n}{V}$$

$$= \frac{1.2348\ \text{mol}}{450\ \text{L}}$$

$$= 0.002\,74\ \text{mol/L}$$

$$= 2.74 \times 10^{-3}\ \text{mol/L}\ \ (3\ \text{significant digits})$$

5. a. Toxicity is the ability of any chemical substance to react with the chemistry of a living organism in such a way as to harm that organism.

   b.

Classification	Example	Classification	Example
Corrosive	detergents	Mutagens	sodium nitrate
Metabolic	lead, mercury, cyanide, carbon monoxide	Teratogens	chemicals in cigarettes
Neurotoxic	nicotine	Carcenogens	PCBs, nicotine

   c. Batteries can contain toxic chemicals and there are such a large number of batteries in use and being continuously discarded.

   d. The battery industry has replaced mercury, an extremely toxic substance, in many batteries.

   e. People put more toxic substances into the environment than industry. This is because there are so many people discarding various wastes. Although you may not think you are discarding very much, when you multiply that amount by millions of people, the amount of waste discarded becomes very large.

   f. The purpose of the Alberta Special Waste Treatment Centre is to eliminate those hazardous wastes which other industries cannot clean up.

   g. The Alberta Special Waste Treatment Centre eliminates most of its hazardous wastes by changing the toxic substance back into the original chemicals it was made from.

Section 3: Activity 1

1. You would need three times the amount or 750 mL of kidney beans.

2. You would need three times the amount or 7.5 mL of basil.

3. If you used 1.0 L of kidney beans, this could feed four times the number of people (16 people).

4. The part of the equation similar to the number of mL is the number of moles or the coefficients. These are the numbers before the formula for each chemical.

5. Reactants is the term used for the ingredients of a chemical reaction.

6. The products are similar to the prepared meal.

7. Stoichiometry is the calculation of quantities involved in chemical reactions. Stoichiometry uses the mole ratio to find various amounts. If you know the number of moles of any chemical in a balanced equation, then you can find the number of moles of any other chemical in the same balanced equation.

8. A chemical equation can give the following:

   - formulas of the chemicals reacted and produced
   - relative amounts of the reactants and products
   - states of all the chemicals involved in the reaction

9. a. 1:3:2 b. 1:1:1:2 c. 1:2:2:1 d. 2:4:3

10. a. $2NaCl_{(s)} \rightarrow 2Na_{(s)} + 1Cl_{2(g)}$

Two moles of solid sodium chloride reacts to form two moles of solid sodium and one mole of chlorine gas.

b. $2HCl_{(aq)} + 1Ba(OH)_{2(aq)} \rightarrow 1BaCl_{2(aq)} + 2H_2O_{(l)}$

Two moles of aqueous hydrogen chloride (hydrochloric acid) reacts with one mole of aqueous barium hydroxide to form one mole of aqueous barium chloride and two moles of liquid water.

c. $1Pb_{(s)} + 2AgNO_{3(aq)} \rightarrow 1Pb(NO_3)_{2(aq)} + 2Ag_{(s)}$

One mole of solid lead reacts with two moles of aqueous silver nitrate to form one mole of aqueous lead(II) nitrate and two moles of solid silver.

d. $2H_{2(g)} + 1O_{2(g)} \rightarrow 2H_2O_{(l)}$

Two moles of hydrogen gas reacts with one mole of oxygen gas to form two moles of liquid water.

e. $1H_3PO_{4(aq)} + 3KOH_{(aq)} \rightarrow 1K_3PO_{4(aq)} + 3H_2O_{(l)}$

One mole of aqueous hydrogen phosphate (phosphoric acid) reacts with three moles of aqueous potassium hydroxide to form one mole of aqueous potassium phosphate and three moles of liquid water.

Note: In a., you can substitute the word decomposes for the word reacts. In b. and e., you can substitute the word neutralizes for the words reacts with. Instead of using the words to form, the words yields or produces can be used.

11. a. You should react twice the amount of aluminum (8 mol).

b. You should react three times the amount of oxygen (9 mol).

12. a. $\frac{1 \text{ mol of } H_3PO_{4(aq)}}{3 \text{ mol of } H_2O_{(l)}}$ or $\frac{3 \text{ mol of } H_2O_{(l)}}{1 \text{ mol of } H_3PO_{4(aq)}}$ c. $\frac{1 \text{ mol of } Sr(NO_3)_{2(aq)}}{2 \text{ mol of } NaNO_{3(aq)}}$ or $\frac{2 \text{ mol of } NaNO_{3(aq)}}{1 \text{ mol of } Sr(NO_3)_{2(aq)}}$

b. $\frac{2 \text{ mol of } Fe_2O_{3(s)}}{3 \text{ mol of } O_{2(g)}}$ or $\frac{3 \text{ mol of } O_{2(g)}}{2 \text{ mol of } Fe_2O_{3(s)}}$

13. a. $0.200 \cancel{\text{ mol of } Ni_{(s)}} \times \frac{2 \text{ mol of } Ag_{(s)}}{1 \cancel{\text{ mol of } Ni_{(s)}}} = 0.400 \text{ mol of } Ag_{(s)}$

b. $0.16 \cancel{\text{ mol of } Al_{(s)}} \times \frac{3 \text{ mol of } O_{2(g)}}{4 \cancel{\text{ mol of } Al_{(s)}}} = 0.12 \text{ mol of } O_{2(g)}$

c. $0.324 \cancel{\text{ mol of } Sr(NO_3)_{2(aq)}} \times \dfrac{1 \text{ mol of } SrCO_{3(s)}}{1 \cancel{\text{ mol of } Sr(NO_3)_{2(aq)}}} = 0.324 \text{ mol of } SrCO_{3(s)}$

d. $2.3 \times 10^{-4} \cancel{\text{ mol of } H_3PO_{4(aq)}} \times \dfrac{3 \text{ mol of } LiOH_{(aq)}}{1 \cancel{\text{ mol of } H_3PO_{4(aq)}}} = 6.9 \times 10^{-4} \text{ mol of } LiOH_{(aq)}$

14. **Textbook question 1:**

$$1.0 \cancel{\text{ mol of } NH_{3(aq)}} \times \frac{1 \text{ mol of } NH_4NO_{3(aq)}}{1 \cancel{\text{ mol of } NH_{3(aq)}}} = 1.0 \text{ mol of } NH_4NO_{3(aq)}$$

Textbook question 2:

$$458 \cancel{\text{ mol of } NH_4NO_{3(aq)}} \times \frac{1 \text{ mol of } NH_{3(aq)}}{1 \cancel{\text{ mol of } NH_4NO_{3(aq)}}} = 458 \text{ mol of } NH_{3(aq)}$$

Textbook question 3:

$$42 \cancel{\text{ mol of } NH_{3(aq)}} \times \frac{1 \text{ mol of } H_2SO_{4(aq)}}{2 \cancel{\text{ mol of } NH_{3(aq)}}} = 21 \text{ mol of } H_2SO_{4(aq)}$$

Note: The question states that ammonia is a gas, and the balanced equation states that ammonia is an aqueous solution (page 277 of *Visions 2*). The state of ammonia has no bearing on the mole ratio; therefore, ammonia can be listed as either a gas or an aqueous solution.

Textbook question 4:

$$7.5 \cancel{\text{ mol of } NH_{3(aq)}} \times \frac{1 \text{ mol of } (NH_4)_2SO_{4(aq)}}{2 \cancel{\text{ mol of } NH_{3(aq)}}} = 3.8 \text{ mol of } (NH_4)_2SO_{4(aq)} \quad (2 \text{ significant digits})$$

Textbook question 5(a):

$$234 \cancel{\text{ mol of } H_3PO_{4(aq)}} \times \frac{1 \text{ mol of } (NH_4)_3PO_{4(aq)}}{1 \cancel{\text{ mol of } H_3PO_{4(aq)}}} = 234 \text{ mol of } (NH_4)_3PO_{4(aq)}$$

Textbook question 5(b):

$$0.105 \cancel{\text{ mol of } H_3PO_{4(aq)}} \times \frac{1 \text{ mol of } (NH_4)_3PO_{4(aq)}}{1 \cancel{\text{ mol of } H_3PO_{4(aq)}}} = 0.105 \text{ mol of } (NH_4)_3PO_{4(aq)}$$

Textbook question 5(c):

$$27 \cancel{\text{ mol of } H_3PO_{4(aq)}} \times \frac{1 \text{ mol of } (NH_4)_3PO_{4(aq)}}{1 \cancel{\text{ mol of } H_3PO_{4(aq)}}} = 27 \text{ mol of } (NH_4)_3PO_{4(aq)}$$

Section 3: Activity 2

1. A balance measures the mass of a chemical.
2. Molar mass is used to convert moles into grams.
3. No, the mole ratio remains the same no matter what quantities are used.
4. To convert Grams A to Moles A, you must use **Molar mass A**.
5. To convert Moles A to Moles B, you must use the **Mole ratio**.
6. The mole ratio is taken from the coefficients of the two substances in the balanced equation.
7. To convert Moles B to Grams B, you must use **Molar mass B**.
8. In the two examples, and all situations where you are given grams and asked for grams, there are three major steps:

   Step 1: Calculate the number of moles of the given substance.

   Step 2: Multiply the answer from Step 1 by the mole ratio.

   Step 3: Multiply the answer from Step 2 by the molar mass of the required substance.

9. **Textbook question 1(a):**

Unit Analysis Method

Calculate the number of moles of $CH_{4(g)}$.

$$\text{molar mass} = [12.01 + (4 \times 1.01)]\ \text{g/mol}$$
$$= 16.05\ \text{g/mol}$$

$$13.0\ \text{g} \times \frac{1\ \text{mol}}{16.05\ \text{g}} = 0.809\,97\ \text{mol}$$

Calculate the number of moles of $O_{2(g)}$.

$$0.809\,97\ \text{mol} \times \frac{2\ \text{mol of } O_{2(g)}}{1\ \text{mol of } CH_{4(g)}} = 1.6199\ \text{mol}$$

Calculate the mass of $O_{2(g)}$.

$$\text{molar mass} = 2 \times 16.00\ \text{g/mol}$$
$$= 32.00\ \text{g/mol}$$

$$1.6199\ \text{mol} \times \frac{32.00\ \text{g}}{1\ \text{mol}} = 51.8\ \text{g}\ \text{(3 significant digits)}$$

Formula Method

data:

$1CH_{4(g)}$	$2O_{2(g)}$
$M = 12.01 + (4 \times 1.01)$ $= 16.05\ \text{g/mol}$	$M = 2 \times 16.00$ $= 32.00\ \text{g/mol}$
$m = 13.0\ \text{g}$	$m = ?$

solution: $n = \frac{m}{M} = \frac{13.0\ \text{g}}{16.05\ \text{g/mol}}$

$$= 0.809\,97\ \text{mol}$$

$$0.809\,97\ \text{mol} \times \frac{2\ \text{mol of } O_{2(g)}}{1\ \text{mol of } CH_{4(g)}} = 1.6199\ \text{mol}$$

$$m = nM = 1.6199\ \text{mol} \times 32.00\ \text{g/mol}$$
$$= 51.8\ \text{g}\ \text{(3 significant digits)}$$

Textbook question 1(b):

Mass of Carbon Dioxide

Unit Analysis Method

Calculate the number of moles of $CH_{4(g)}$.

$$\text{molar mass} = [12.01 + (4 \times 1.01)]\ \text{g/mol}$$
$$= 16.05\ \text{g/mol}$$

$$13.0\ \text{g} \times \frac{1\ \text{mol}}{16.05\ \text{g}} = 0.809\ 97\ \text{mol}$$

Calculate the number of moles of $CO_{2(g)}$.

$$0.809\ 97\ \text{mol} \times \frac{1\ \text{mol of } CO_{2(g)}}{1\ \text{mol of } CH_{4(g)}} = 0.809\ 97\ \text{mol}$$

Calculate the mass of $CO_{2(g)}$.

$$\text{molar mass} = [12.01 + (2 \times 16.00)]\ \text{g/mol}$$
$$= 44.01\ \text{g/mol}$$

$$0.809\ 97\ \text{mol} \times \frac{44.01\ \text{g}}{1\ \text{mol}} = 35.6\ \text{g}\ \text{(3 significant digits)}$$

Formula Method

data:

$1CH_{4(g)}$	$1CO_{2(g)}$
$M = 12.01 + (4 \times 1.01)$ $= 16.05\ \text{g/mol}$	$M = 12.01 + (2 \times 16.00)$ $= 44.01\ \text{g/mol}$
$m = 13.0\ \text{g}$	$m = ?$

solution: $n = \frac{m}{M} = \frac{13.0\ \text{g}}{16.05\ \text{g/mol}}$
$= 0.809\ 97\ \text{mol}$

$$0.809\ 97\ \text{mol} \times \frac{1\ \text{mol of } CO_{2(g)}}{1\ \text{mol of } CH_{4(g)}} = 0.809\ 97\ \text{m}$$

$m = nM = 0.809\ 97\ \text{mol} \times 44.01\ \text{g/mol}$
$= 35.6\ \text{g}\ \text{(3 significant digits)}$

Mass of Water

Unit Analysis Method

Calculate the number of moles of $CH_{4(g)}$.

$$\text{molar mass} = [12.01 + (4 \times 1.01)]\ \text{g/mol}$$
$$= 16.05\ \text{g/mol}$$

$$13.0\ \text{g} \times \frac{1\ \text{mol}}{16.05\ \text{g}} = 0.809\ 97\ \text{mol}$$

Calculate the number of moles of $H_2O_{(g)}$.

$$0.809\ 97\ \text{mol} \times \frac{2\ \text{mol of } H_2O_{(g)}}{1\ \text{mol of } CH_{4(g)}} = 1.6199\ \text{mol}$$

Calculate the mass of $H_2O_{(g)}$.

$$\text{molar mass} = [(2 \times 1.01) + 16.00]\ \text{g/mol}$$
$$= 18.02\ \text{g/mol}$$

$$1.6199\ \text{mol} \times \frac{18.02\ \text{g}}{1\ \text{mol}} = 29.2\ \text{g}\ \text{(3 significant digits)}$$

Formula Method

data:

$1CH_{4(g)}$	$2H_2O_{(g)}$
$M = 12.01 + (4 \times 1.01)$ $= 16.05\ \text{g/mol}$	$M = (2 \times 1.01) + 16.00$ $= 18.02\ \text{g/mol}$
$m = 13.0\ \text{g}$	$m = ?$

solution: $n = \frac{m}{M} = \frac{13.0\ \text{g}}{16.05\ \text{g/mol}}$
$= 0.809\ 97\ \text{mol}$

$$0.809\ 97\ \text{mol} \times \frac{2\ \text{mol of } H_2O_{(g)}}{1\ \text{mol of } CH_{4(g)}} = 1.6199\ \text{mo}$$

$m = nM = 1.6199\ \text{mol} \times 18.02\ \text{g/mol}$
$= 29.2\ \text{g}\ \text{(3 significant digits)}$

Textbook question 1(c): The Law of Conservation of Mass states that mass is neither created nor destroyed in a chemical reaction. This means that the total mass of the reactants must be equal to the total mass of the products.

$$13.0\text{ g} + 51.8\text{ g} = 35.6\text{ g} + 29.2\text{ g}$$
$$64.8\text{ g} = 64.8\text{ g}\ \text{(3 significant digits)}$$

According to the equation, mass is conserved in the reaction.

Textbook question 2(a):

Unit Analysis Method

Calculate the number of moles of $KClO_{3(s)}$.

$$\text{molar mass} = 39.10 + 35.45 + (3 \times 16.00)$$
$$= 122.55\text{ g/mol}$$

$$12\text{ g} \times \frac{1\text{ mol}}{122.55\text{ g}} = 0.097\,92\text{ mol}$$

Calculate the number of moles of $O_{2(g)}$.

$$0.097\,92\text{ mol} \times \frac{3\text{ mol of } O_{2(g)}}{2\text{ mol of } KClO_{3(s)}} = 0.1469\text{ mol}$$

Calculate the mass of $O_{2(g)}$.

$$\text{molar mass} = 2 \times 16.00\text{ g/mol}$$
$$= 32.00\text{ g/mol}$$

$$0.1469\text{ mol} \times \frac{32.00\text{ g}}{1\text{ mol}} = 4.7\text{ g}\ \text{(2 significant digits)}$$

Formula Method

data:

$2KClO_{3(s)}$	$3O_{2(g)}$
$M = 39.10 + 35.45 + (3 \times 16.00)$ $= 122.55\text{ g/mol}$	$M = 2 \times 16.00$ $= 32.00\text{ g/mol}$
$m = 12\text{ g}$	$m = ?$

solution:

$$n = \frac{m}{M} = \frac{12\text{ g}}{122.55\text{ g/mol}}$$
$$= 0.097\,92\text{ mol}$$

$$0.097\,92\text{ mol} \times \frac{3\text{ mol of } O_{2(g)}}{2\text{ mol of } KClO_{3(s)}} = 0.1469\text{ mol}$$

$$m = nM = 0.1469\text{ mol} \times 32.00\text{ g/mol}$$
$$= 4.7\text{ g}\ \text{(2 significant digits)}$$

Textbook question 2(b):

Unit Analysis Method

Calculate the number of moles of $O_{2(g)}$.

$$\text{molar mass} = 2 \times 16.00 \text{ g/mol} = 32.00 \text{ g/mol}$$

$$50.0 \cancel{\text{g}} \times \frac{1 \text{ mol}}{32.00 \cancel{\text{g}}} = 1.5625 \text{ mol}$$

Calculate the number of moles of $KClO_{3(s)}$.

$$1.5625 \text{ mol} \times \frac{2 \text{ mol of } KClO_{3(s)}}{3 \text{ mol of } O_{2(g)}} = 1.0417 \text{ mol}$$

Calculate the mass of $KClO_{3(s)}$.

$$\text{molar mass} = 39.10 + 35.45 + (3 \times 16.00) = 122.55 \text{ g/mol}$$

$$1.0417 \cancel{\text{mol}} \times \frac{122.55 \text{ g}}{1 \cancel{\text{mol}}} = 128 \text{ g}$$

(3 significant digits)

Formula Method

data:

$3O_{2(g)}$	$2KClO_{3(s)}$
$M = 2 \times 16.00 = 32.00 \text{ g/mol}$	$M = 39.10 + 35.45 + (3 \times 16.00) = 122.55 \text{ g/mol}$
$m = 50.0 \text{ g}$	$m = ?$

solution: $n = \frac{m}{M} = \frac{50.0 \text{ g}}{32.00 \text{ g/mol}} = 1.5625 \text{ mol}$

$$1.5625 \text{ mol} \times \frac{2 \text{ mol of } KClO_{3(s)}}{3 \text{ mol of } O_{2(g)}} = 1.0417 \text{ mo}$$

$$m = nM = 1.0417 \text{ mol} \times 122.55 \text{ g/mol} = 128 \text{ g} \text{ (3 significant digits)}$$

Textbook question 2(c):

Unit Analysis Method

Calculate the number of moles of $O_{2(g)}$.

$$\text{molar mass} = 2 \times 16.00 \text{ g/mol} = 32.00 \text{ g/mol}$$

$$25.0 \cancel{\text{g}} \times \frac{1 \text{ mol}}{32.00 \cancel{\text{g}}} = 0.781\,25 \text{ mol}$$

Calculate the number of moles of $KCl_{(s)}$.

$$0.781\,25 \text{ mol} \times \frac{2 \text{ mol of } KCl_{(s)}}{3 \text{ mol of } O_{2(g)}} = 0.520\,83 \text{ mol}$$

Calculate the mass of $KCl_{(s)}$.

$$\text{molar mass} = (39.10 + 35.45) \text{ g/mol} = 74.55 \text{ g/mol}$$

$$0.520\,83 \cancel{\text{mol}} \times \frac{74.55 \text{ g}}{1 \cancel{\text{mol}}} = 38.8 \text{ g}$$

(3 significant digits)

Formula Method

data:

$3O_{2(g)}$	$2KCl_{(s)}$
$M = 2 \times 16.00 = 32.00 \text{ g/mol}$	$M = 39.10 + 35.45 = 74.55 \text{ g/mol}$
$m = 25.0 \text{ g}$	$m = ?$

solution: $n = \frac{m}{M} = \frac{25.0 \text{ g}}{32.00 \text{ g/mol}} = 0.781\,25 \text{ mol}$

$$0.781\,25 \text{ mol} \times \frac{2 \text{ mol of } KCl_{(s)}}{3 \text{ mol of } O_{2(g)}} = 0.520\,83 \text{ mo}$$

$$m = nM = 0.520\,83 \text{ mol} \times 74.55 \text{ g/mol} = 38.8 \text{ g} \text{ (3 significant digits)}$$

10. **Unit Analysis Method**

Calculate the number of moles of $(NH_4)_2SO_{4(aq)}$.

$$0.0100 \text{ mol} \times \frac{1 \text{ mol of } (NH_4)_2SO_{4(aq)}}{2 \text{ mol of } NH_{3(aq)}} = 0.005\,00 \text{ mol}$$

Calculate the mass of $(NH_4)_2SO_{4(aq)}$.

$$\begin{aligned}\text{molar mass} &= [(2 \times 14.01) + (8 \times 1.01) + 32.06 + (4 \times 16.00)] \text{ g/mol} \\ &= 132.16 \text{ g/mol}\end{aligned}$$

$$0.005\,00 \text{ mol} \times \frac{132.16 \text{ g}}{1 \text{ mol}} = 0.661 \text{ g} \quad (3 \text{ significant digits})$$

Formula Method

data:

$2NH_{3(aq)}$	$1(NH_4)_2SO_{4(aq)}$
$n = 0.0100$ mol	$M = [(2 \times 14.01) + (8 \times 1.01) + 32.06 + (4 \times 16.00)]$ g/mol $= 132.16$ g/mol
	$m = ?$

solution: $0.0100 \text{ mol} \times \frac{1 \text{ mol of } (NH_4)_2SO_{4(aq)}}{2 \text{ mol of } NH_{3(aq)}} = 0.005\,00 \text{ mol}$

$$\begin{aligned}m = nM &= 0.005\,00 \text{ mol} \times 132.16 \text{ g/mol} \\ &= 0.661 \text{ g} \quad (3 \text{ significant digits})\end{aligned}$$

11. Answers will vary. The following are some possible results. The mass of the watch glass and the evaporating dish was 120.34 g. The mass of the watch glass, evaporating dish, and crystals is 120.82 g. Therefore, the mass of the crystals is 0.48 g.

12. **Textbook question 1:** In this case, the mass of the ammonium sulphate produced is not equal to the theoretical yield. Some possible reasons for the results being low are as follows:

- The initial concentration of the ammonia solution may have been lower than labelled.
- Some solution may have splashed out of the evaporating dish.
- The reaction may not have gone to completion. This means that not all the reactants may have reacted.

Some possible reasons for the results being high are as follows:

- The concentration of the ammonia solution may have been higher than labelled.
- The crystals may not have been completely dry.

Textbook question 2: The design of this experiment would appear to be not acceptable because the actual yield was significantly different from the theoretical yield. The error in this case is greater than 10%. Perhaps the experiment could be repeated several times and an average yield used. You may find your error was less than 10% (percent yield was greater than 90%).

13. **Textbook question 2 (Extension):**

$$\%\text{yield} = \frac{\text{actual mass}}{\text{predicted mass}} \times 100$$
$$= \frac{0.48\ \text{g}}{0.661\ \text{g}} \times 100$$
$$= 73\%\ \text{(2 significant digits)}$$

14. $CaCl_{2(aq)} + Na_2CO_{3(aq)} \rightarrow CaCO_{3(s)} + 2NaCl_{(aq)}$

Unit Analysis Method

Calculate the number of moles of $CaCl_{2(aq)}$.

$$\text{molar mass} = [40.08 + (2 \times 35.45)]\ \text{g/mol}$$
$$= 110.98\ \text{g/mol}$$

$$1.5\ \text{g} \times \frac{1\ \text{mol}}{110.98\ \text{g}} = 0.013\,52\ \text{mol}$$

Calculate the number of moles of $CaCO_{3(s)}$.

$$0.013\,52\ \text{mol} \times \frac{1\ \text{mol of } CaCO_{3(s)}}{1\ \text{mol of } CaCl_{2(aq)}} = 0.013\,52\ \text{mol}$$

Calculate the mass of $CaCO_{3(s)}$.

$$\text{molar mass} = [40.08 + 12.01 + (3 \times 16.00)]\ \text{g/mol}$$
$$= 100.09\ \text{g/mol}$$

$$0.013\,52\ \text{mol} \times \frac{100.09\ \text{g}}{1\ \text{mol}} = 1.4\ \text{g}$$

(2 significant digits)

Formula Method

data:

$1CaCl_{2(aq)}$	$1CaCO_{3(aq)}$
$M = 40.08 + (2 \times 35.45)$ $= 110.98\ \text{g/mol}$	$M = 40.08 + 12.01 + (3 \times 16.00)$ $= 100.09\ \text{g/mol}$
$m = 1.5\ \text{g}$	$m = ?$

solution:

$$n = \frac{m}{M} = \frac{1.5\ \text{g}}{110.98\ \text{g/mol}}$$
$$= 0.013\,52\ \text{mol}$$

$$0.013\,52\ \text{mol} \times \frac{1\ \text{mol of } CaCO_{3(s)}}{1\ \text{mol of } CaCl_{2(aq)}} = 0.013\,52\ \text{mol}$$

$$m = nM = 0.013\,52\ \text{mol} \times 100.09\ \text{g/mol}$$
$$= 1.4\ \text{g}\ \text{(2 significant digits)}$$

15. Results will vary. One possible answer is given. The mass of the filter paper is 1.2 g. The mass of the filter paper and the precipitate is 2.5 g. Therefore, the mass of the precipitate is $2.5\ \text{g} - 1.2\ \text{g} = 1.3\ \text{g}$.

16. The actual yield was not exactly the same as the theoretical yield. The theoretical yield was 1.4 g and the actual yield was 1.3 g. The possible reasons for the difference between the actual yield and the theoretical yield are as follows:

- The measure of the masses of the reactants and the products may have been off.
- The products may not have been completely dry.
- Some precipitate may have remained in the beaker or slipped down between the filter paper and the funnel.

17. $$\%\text{yield} = \frac{\text{actual mass}}{\text{predicted mass}} \times 100$$
$$= \frac{1.3\ \text{g}}{1.4\ \text{g}} \times 100$$
$$= 93\% \text{ (2 significant digits)}$$

18. Three reasons for a percent yield that is less than 100% are as follows:

- Some of the reactants or products are lost during the reaction or separation process.
- There are other reactions that happen that use up the chemicals in the reaction.
- Some of the reactants do not react; there are leftovers.

19. a. **Unit Analysis Method**

Calculate the number of moles of $N_{2(g)}$.

$$\text{molar mass} = 2 \times 14.01\ \text{g/mol}$$
$$= 28.02\ \text{g/mol}$$

$$100\ \text{g} \times \frac{1\ \text{mol}}{28.02\ \text{g}} = 3.5689\ \text{mol}$$

Calculate the number of moles of $NH_{3(g)}$.

$$3.5689\ \text{mol} \times \frac{2\ \text{mol of } NH_{3(g)}}{1\ \text{mol of } N_{2(g)}} = 7.1378\ \text{mol}$$

Calculate the mass of $NH_{3(g)}$.

$$\text{molar mass} = [14.01 + (3 \times 1.01)]\ \text{g/mol}$$
$$= 17.04\ \text{g/mol}$$

$$7.1378\ \text{mol} \times \frac{17.04\ \text{g}}{1\ \text{mol}} = 122\ \text{g}$$
(3 significant digits)

Formula Method

data:

$1N_{2(g)}$	$2NH_{3(g)}$
$M = 2 \times 14.01\ \text{g/mol}$ $= 28.02\ \text{g/mol}$	$M = [14.01 + (3 \times 1.01)]\ \text{g/mol}$ $= 17.04\ \text{g/mol}$
$m = 100\ \text{g}$	$m = ?$

solution: $$n = \frac{m}{M} = \frac{100\ \text{g}}{28.02\ \text{g/mol}}$$
$$= 3.5689\ \text{mol}$$

$$3.5689\ \text{mol} \times \frac{2\ \text{mol of } NH_{3(g)}}{1\ \text{mol of } N_{2(g)}} = 7.1378\ \text{mol}$$

$$m = nM = 7.1378\ \text{mol} \times 17.04\ \text{g/mol}$$
$$= 122\ \text{g (3 significant digits)}$$

b. $\%\text{yield} = \dfrac{\text{actual mass}}{\text{predicted mass}} \times 100$

$= \dfrac{105\ \text{g}}{122\ \text{g}} \times 100$

$= 86.1\%$ (3 significant digits)

20. a. **Unit Analysis Method**

Calculate the number of moles of $Na_2CO_{3(aq)}$.

$\text{molar mass} = \left[(2 \times 22.99) + 12.01 + (3 \times 16.00)\right] \text{g/mol}$

$= 105.99\ \text{g/mol}$

$2.50\ \text{g} \times \dfrac{1\ \text{mol}}{105.99\ \text{g}} = 0.023\,587\ \text{mol}$

Calculate the number of moles of $BaCO_{3(s)}$.

$0.023\,587\ \text{mol} \times \dfrac{1\ \text{mol of } BaCO_{3(s)}}{1\ \text{mol of } Na_2CO_{3(aq)}} = 0.023\,587\ \text{mol}$

Calculate the mass of $BaCO_{3(s)}$.

$\text{molar mass} = \left[137.33 + 12.01 + (3 \times 16.00)\right] \text{g/mol}$

$= 197.34\ \text{g/mol}$

$0.023\,587\ \text{mol} \times \dfrac{197.34\ \text{g}}{1\ \text{mol}} = 4.65\ \text{g}$ (3 significant digits)

Formula Method

data:

$1Na_2CO_{3(aq)}$	$1BaCO_{3(s)}$
$M = (2 \times 22.99) + 12.01 + (3 \times 16.00)$ $= 105.99\ \text{g/mol}$	$M = 137.33 + 12.01 + (3 \times 16.00)$ $= 197.34\ \text{g/mol}$
$m = 2.50\ \text{g}$	$m = ?$

solution: $n = \frac{m}{M} = \frac{2.50\ \text{g}}{105.99\ \text{g/mol}}$

$= 0.023\,587\ \text{mol}$

$$0.023\,587\ \text{mol} \times \frac{1\ \text{mol of } BaCO_{3(s)}}{1\ \text{mol of } Na_3CO_{2(aq)}} = 0.023\,587\ \text{mol}$$

$m = nM = 0.023\,587\ \text{mol} \times 197.34\ \text{g/mol}$

$= 4.65\ \text{g}$ (3 significant digits)

b. $\%\text{yield} = \frac{\text{actual mass}}{\text{predicted mass}} \times 100$

$= \frac{4.32\ \text{g}}{4.65\ \text{g}} \times 100$

$= 92.9\%$ (3 significant digits)

c. To produce 4.32 g of the $BaCO_{3(s)}$, you will need 92.9% of the amount of $Na_2CO_{3(aq)}$.

$2.50\ \text{g} \times 0.929 = 2.32\ \text{g}$ (3 significant digits)

Section 3: Follow-up Activities

Extra Help

1. a. The coefficient in front of $Al_2O_{3(s)}$ tells you the number of moles. It is 2.

b. $M = 2 \times 16.00\ \text{g/mol}$

$= 32.00\ \text{g/mol}$

Note: You do not use the coefficient to calculate the molar mass.

c. $M = [(2 \times 26.98) + (3 \times 16.00)]\ \text{g/mol}$

$= 101.96\ \text{g/mol}$

d. The coefficient of oxygen is 3.

e. The subscript of oxygen gas is 2.

2. a. $0.300\ \cancel{\text{mol of } Cl_{2(g)}} \times \frac{2\ \text{mol of } NaCl_{(s)}}{1\ \cancel{\text{mol of } Cl_{2(g)}}} = 0.600\ \text{mol of } NaCl_{(s)}$

b. $0.600\ \cancel{\text{mol of } HCl_{(aq)}} \times \frac{2\ \text{mol of } AlCl_{3(aq)}}{6\ \cancel{\text{mol of } HCl_{(aq)}}} = 0.200\ \text{mol of } AlCl_{3(aq)}$

c. $0.400\ \cancel{\text{mol of } KOH_{(aq)}} \times \frac{1\ \text{mol of } H_2SO_{4(aq)}}{2\ \cancel{\text{mol of } KOH_{(aq)}}} = 0.200\ \text{mol of } H_2SO_{4(aq)}$

3. a. **Unit Analysis Method**

Calculate the number of moles of $Cl_{2(g)}$.

$$\text{molar mass} = 2 \times 35.45 \text{ g/mol} = 70.90 \text{ g/mol}$$

$$3.50 \text{ g} \times \frac{1 \text{ mol}}{70.90 \text{ g}} = 0.049\,365 \text{ mol}$$

Calculate the number of moles of $NaCl_{(s)}$.

$$0.049\,365 \text{ mol} \times \frac{2 \text{ mol of } NaCl_{(s)}}{1 \text{ mol of } Cl_{2(g)}} = 0.098\,731 \text{ mol}$$

Calculate the mass of $NaCl_{(s)}$.

$$\text{molar mass} = (22.99 + 35.45) \text{ g/mol} = 58.44 \text{ g/mol}$$

$$0.098\,731 \text{ mol} \times \frac{58.44 \text{ g}}{1 \text{ mol}} = 5.77 \text{ g}$$

(3 significant digits)

Formula Method

data:

$1Cl_{2(g)}$	$2NaCl_{(s)}$
$M = 2 \times 35.45 \text{ g/mol} = 70.90 \text{ g/mol}$	$M = (22.99 + 35.45) \text{ g/mol} = 58.44 \text{ g/mol}$
$m = 3.50 \text{ g}$	$m = ?$

solution:

$$n = \frac{m}{M} = \frac{3.50 \text{ g}}{70.90 \text{ g/mol}} = 0.049\,365 \text{ mol}$$

$$0.049\,365 \text{ mol} \times \frac{2 \text{ mol of } NaCl_{(s)}}{1 \text{ mol of } Cl_{2(g)}} = 0.098\,731 \text{ m}$$

$$m = nM = 0.098\,731 \text{ mol} \times 58.44 \text{ g/mol} = 5.77 \text{ g} \text{ (3 significant digits)}$$

b. **Unit Analysis Method**

Calculate the number of moles of $Al_{(s)}$.

$$\text{molar mass} = 26.98 \text{ g/mol}$$

$$2.70 \text{ g} \times \frac{1 \text{ mol}}{26.98 \text{ g}} = 0.100\,07 \text{ mol}$$

Calculate the number of moles of $AlCl_{3(aq)}$.

$$0.100\,07 \text{ mol} \times \frac{2 \text{ mol of } AlCl_{3(aq)}}{2 \text{ mol of } Al_{(s)}} = 0.100\,07 \text{ mol}$$

Calculate the mass of $AlCl_{3(aq)}$.

$$\text{molar mass} = [26.98 + (3 \times 35.45)] \text{ g/mol} = 133.33 \text{ g/mol}$$

$$0.100\,07 \text{ mol} \times \frac{133.33 \text{ g}}{1 \text{ mol}} = 13.3 \text{ g} \text{ (3 significant digits)}$$

Formula Method

data:

$2Al_{(s)}$	$2AlCl_{3(aq)}$
$M = 26.98 \text{ g/mol}$	$M = 26.98 + (3 \times 35.45) = 133.33 \text{ g/mol}$
$m = 2.70 \text{ g}$	$m = ?$

solution:

$$n = \frac{m}{M} = \frac{2.70 \text{ g}}{26.98 \text{ g/mol}} = 0.100\,07 \text{ mol}$$

$$0.100\,07 \text{ mol} \times \frac{2 \text{ mol of } AlCl_{3(aq)}}{2 \text{ mol of } Al_{(s)}} = 0.100\,07 \text{ mo}$$

$$m = nM = 0.100\,07 \text{ mol} \times 133.33 \text{ g/mol} = 13.3 \text{ g} \text{ (3 significant digits)}$$

c. **Unit Analysis Method**

Calculate the number of moles of $KOH_{(aq)}$.

$$\text{molar mass} = (39.10 + 16.00 + 1.01)\ \text{g/mol}$$
$$= 56.11\ \text{g/mol}$$

$$2.80\ \text{g} \times \frac{1\ \text{mol}}{56.11\ \text{g}} = 0.049\ 902\ \text{mol}$$

Calculate the number of moles of $H_2SO_{4(aq)}$.

$$0.049\ 902\ \text{mol} \times \frac{1\ \text{mol of } H_2SO_{4(aq)}}{2\ \text{mol of } KOH_{(aq)}} = 0.024\ 951\ \text{mol}$$

Calculate the mass of $H_2SO_{4(aq)}$.

$$\text{molar mass} = [(2 \times 1.01) + 32.06 + (4 \times 16.00)]\ \text{g/mol}$$
$$= 98.08\ \text{g/mol}$$

$$0.024\ 951\ \text{mol} \times \frac{98.08\ \text{g}}{1\ \text{mol}} = 2.45\ \text{g}\ \ (3\ \text{significant digits})$$

Formula Method

data:

$2KOH_{(aq)}$	$1H_2SO_{4(aq)}$
$M = (39.10 + 16.00 + 1.01)\ \text{g/mol}$ $= 56.11\ \text{g/mol}$	$M = [(2 \times 1.01) + 32.06 + (4 \times 16.00)]\ \text{g/mol}$ $= 98.08\ \text{g/mol}$
$m = 2.80\ \text{g}$	$m = ?$

solution: $n = \frac{m}{M} = \frac{2.80\ \text{g}}{56.11\ \text{g/mol}}$

$$= 0.049\ 902\ \text{mol}$$

$$0.049\ 902\ \text{mol} \times \frac{1\ \text{mol of } H_2SO_{4(aq)}}{2\ \text{mol of } KOH_{(aq)}} = 0.024\ 951\ \text{mol}$$

$$m = nM = 0.024\ 951\ \text{mol} \times 98.08\ \text{g/mol}$$
$$= 2.45\ \text{g}\ \ (3\ \text{significant digits})$$

4. a. $\%\text{yield} = \dfrac{\text{actual mass}}{\text{predicted mass}} \times 100$

b. $\%\text{yield} = \dfrac{\text{actual mass}}{\text{predicted mass}} \times 100$

$= \dfrac{2.55\ \text{g}}{2.60\ \text{g}} \times 100$

$= 98.1\%$ (3 significant digits)

Enrichment

1. **Textbook question 5:**

Unit Analysis Method

Calculate the number of moles of $NH_{3(g)}$.

$\text{molar mass} = [14.01 + (3 \times 1.01)]\ \text{g/mol}$

$= 17.04\ \text{g/mol}$

$1.0 \times 10^3\ \cancel{\text{g}} \times \dfrac{1\ \text{mol}}{17.04\ \cancel{\text{g}}} = 58.69\ \text{mol}$

Calculate the number of moles of urea.

$58.69\ \text{mol} \times \dfrac{1\ \text{mol of } (NH_2)_2CO_{(s)}}{2\ \text{mol of } NH_{3(g)}} = 29.34\ \text{mol}$

Calculate the mass of $(NH_2)_2CO_{(s)}$.

$\text{molar mass} = [(2 \times 14.01) + (4 \times 1.01) + 12.01 + 16.00]\ \text{g/mol}$

$= 60.07\ \text{g/mol}$

$29.34\ \cancel{\text{mol}} \times \dfrac{60.07\ \text{g}}{1\ \cancel{\text{mol}}} = 1.8 \times 10^3\ \text{g or } 1.8\ \text{kg}$ (2 significant digits)

Formula Method

data:

$2NH_{3(g)}$	$1(NH_2)_2CO_{(s)}$
$M = [14.01 + (3 \times 1.01)]\ \text{g/mol}$ $= 17.04\ \text{g/mol}$	$M = [(2 \times 14.01) + (4 \times 1.01) + 12.01 + 16.00]\ \text{g/mol}$ $= 60.07\ \text{g/mol}$
$m = 1.0\ \text{kg}$ $= 1.0 \times 10^3\ \text{g}$	$m = ?$

solution: $n = \frac{m}{M} = \frac{1.0 \times 10^3 \text{ g}}{17.04 \text{ g/mol}}$

$= 58.69 \text{ mol}$

$$58.69 \text{ mol} \times \frac{1 \text{ mol of } (NH_2)_2CO_{(s)}}{2 \text{ mol of } NH_{3(g)}} = 29.34 \text{ mol}$$

$m = nM = 29.34 \text{ mol} \times 60.07 \text{ g/mol}$

$= 1.8 \times 10^3 \text{ g or } 1.8 \text{ kg}$ (2 significant digits)

2. **Textbook question 11(a):**

$$2.5 \cancel{\text{ mol of } Fe_2O_{3(s)}} \times \frac{2 \text{ mol of } Fe_3O_{4(s)}}{3 \cancel{\text{ mol of } Fe_2O_{3(s)}}} = 1.7 \text{ mol of } Fe_3O_{4(s)} \text{ (2 significant digits)}$$

Textbook question 11(b):

$$5.0 \cancel{\text{ mol of } Fe_3O_{4(s)}} \times \frac{3 \text{ mol of } FeO_{(s)}}{1 \cancel{\text{ mol of } Fe_3O_{4(s)}}} = 15 \text{ mol of } FeO_{(s)} \text{ (2 significant digits)}$$

Textbook question 11(c):

$$16 \cancel{\text{ mol of } FeO_{(s)}} \times \frac{1 \text{ mol of } Fe_{(l)}}{1 \cancel{\text{ mol of } FeO_{(s)}}} = 16 \text{ mol of } Fe_{(l)} \text{ (2 significant digits)}$$

Textbook question 11(d):

Unit Analysis Method

Calculate the number of moles of $Fe_{(l)}$.

$$1.0 \text{ mol} \times \frac{1 \text{ mol of } Fe_{(l)}}{1 \text{ mol of } FeO_{(s)}} = 1 \text{ mol}$$

Calculate the mass of $Fe_{(l)}$.

molar mass = 55.85 g/mol

$$1.0 \cancel{\text{ mol}} \times \frac{55.85 \text{ g}}{1 \cancel{\text{ mol}}} = 56 \text{ g (2 significant digits)}$$

Formula Method

data:

$1FeO_{(s)}$	$1Fe_{(l)}$
$n = 1.0$ mol	$M = 55.85$ g/mol
	$m = ?$

solution: $1.0 \text{ mol} \times \frac{1 \text{ mol of } Fe_{(l)}}{1 \text{ mol of } FeO_{(s)}} = 1.0 \text{ mol}$

$m = nM = 1.0 \text{ mol} \times 55.85 \text{ g/mol}$

$= 56 \text{ g}$ (2 significant digits)

Textbook question 11(e):

Unit Analysis Method

Calculate the number of moles of $Fe_3O_{4(s)}$.

$$\text{molar mass} = [(3 \times 55.85) + (4 \times 16.00)]\ \text{g/mol}$$
$$= 231.55\ \text{g/mol}$$

$$106\ \text{g} \times \frac{1\ \text{mol}}{231.55\ \text{g}} = 0.457\,78\ \text{mol}$$

Calculate the number of moles of $Fe_{(l)}$. (Each molecule of Fe_3O_4 has three atoms of Fe.)

$$0.457\,78\ \text{mol} \times \frac{3\ \text{mol of Fe}_{(l)}}{1\ \text{mol of Fe}_3O_{4(s)}} = 1.3734\ \text{mol}$$

Calculate the mass of $Fe_{(l)}$.

$$\text{molar mass} = 55.85\ \text{g/mol}$$

$$1.3734\ \text{mol} \times \frac{55.85\ \text{g}}{1\ \text{mol}} = 76.7\ \text{g}$$

(3 significant digits)

Formula Method

data:

$1Fe_3O_{4(s)}$	$3Fe_{(l)}$
$M = (3 \times 55.85) + (4 \times 16.00)$ $= 231.55\ \text{g/mol}$	$M = 55.85\ \text{g/mol}$
$m = 106\ \text{g}$	$m = ?$

solution:

$$n = \frac{m}{M} = \frac{106\ \text{g}}{231.55\ \text{g/mol}}$$
$$= 0.457\,78\ \text{mol}$$

$$0.457\,78\ \text{mol} \times \frac{3\ \text{mol of Fe}_{(l)}}{1\ \text{mol of Fe}_3O_{4(s)}} = 1.3734\ \text{mol}$$

$$m = nM = 1.3734\ \text{mol} \times 55.85\ \text{g/mol}$$
$$= 76.7\ \text{g}\ \ (3\ \text{significant digits})$$

3. Ammonia is an important raw material. Approximately 80% is used in fertilizers, 5% in plastics and fibres, and 5% in explosives. Ammonia gas is used as a fertilizer, in paper productions, in nitric acid production, and in refrigerants.

4. The equation for this reaction is as follows:

$$3CaCl_{2(aq)} + 2Na_3PO_{4(aq)} \rightarrow Ca_3(PO_4)_{2(s)} + 6NaCl_{(aq)}$$

To find the percent yield, you must first find the theoretical yield.

Unit Analysis Method

Calculate the number of moles of $CaCl_{2(aq)}$.

$$\text{molar mass} = [40.08 + (2 \times 35.45)]\ \text{g/mol}$$
$$= 110.98\ \text{g/mol}$$

$$3.50\ \text{g} \times \frac{1\ \text{mol}}{110.98\ \text{g}} = 0.031\,537\ \text{mol}$$

Calculate the number of moles of $Ca_3(PO_4)_{2(s)}$.

$$0.031\,537 \text{ mol} \times \frac{1 \text{ mol of } Ca_3(PO_4)_{2(s)}}{3 \text{ mol of } CaCl_{2(aq)}} = 0.010\,512 \text{ mol}$$

Calculate the mass of $Ca_3(PO_4)_{2(s)}$.

$$\begin{aligned}\text{molar mass} &= [(3 \times 40.08) + (2 \times 30.97) + (8 \times 16.00)] \text{ g / mol} \\ &= 310.18 \text{ g / mol}\end{aligned}$$

$$0.010\,512 \cancel{\text{mol}} \times \frac{310.18 \text{ g}}{1 \cancel{\text{mol}}} = 3.26 \text{ g} \quad (3 \text{ significant digits})$$

Formula Method

data:

$2CaCl_{2(aq)}$	$1Ca_3(PO_4)_{2(s)}$
$M = [40.08 + (2 \times 35.45)]$ g / mol $= 110.98$ g / mol	$M = [(3 \times 40.08) + (2 \times 30.97) + (8 \times 16.00)]$ g / mol $= 310.18$ g / mol
$m = 3.50$ g	$m = ?$

solution: $$\begin{aligned}n = \frac{m}{M} &= \frac{3.50 \text{ g}}{110.98 \text{ g / mol}} \\ &= 0.031\,537 \text{ mol}\end{aligned}$$

$$0.031\,537 \text{ mol} \times \frac{1 \text{ mol of } Ca_3(PO_4)_{2(s)}}{3 \text{ mol of } CaCl_{2(aq)}} = 0.010\,512 \text{ mol}$$

$$\begin{aligned}m = nM &= 0.010\,512 \text{ mol} \times 310.18 \text{ g / mol} \\ &= 3.26 \text{ g} \quad (3 \text{ significant digits})\end{aligned}$$

$$\begin{aligned}\%\text{yield} &= \frac{\text{actual mass}}{\text{predicted mass}} \times 100 \\ &= \frac{2.98 \text{ g}}{3.26 \text{ g}} \times 100 \\ &= 91.4\% \quad (3 \text{ significant digits})\end{aligned}$$

5. $2NaOH_{(aq)} + H_2SO_{4(l)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)}$

Unit Analysis Method

Calculate the number of moles of $H_2SO_{4(l)}$.

$$\text{molar mass} = [(2 \times 1.01) + 32.06 + (4 \times 16.00)]\ g/mol$$
$$= 98.08\ g/mol$$

$$10.0\ \cancel{g} \times \frac{1\ mol}{98.08\ \cancel{g}} = 0.101\,96\ mol$$

Calculate the number of moles of $NaOH_{(aq)}$.

$$0.101\,96\ mol \times \frac{2\ mol\ of\ NaOH_{(aq)}}{1\ mol\ of\ H_2SO_{4(l)}} = 0.203\,92\ mol$$

Calculate the mass of $NaOH_{(aq)}$.

$$\text{molar mass} = (22.99 + 16.00 + 1.01)\ g/mol$$
$$= 40.00\ g/mol$$

$$0.203\,92\ \cancel{mol} \times \frac{40.00\ g}{1\ \cancel{mol}} = 8.16\ g\ \text{(3 significant digits)}$$

Formula Method

data:

$1H_2SO_{4(aq)}$	$2NaOH_{(aq)}$
$M = [(2 \times 1.01) + 32.06 + (4 \times 16.00)]\ g/mol$ $= 98.08\ g/mol$	$M = [22.99 + 16.00 + 1.01]\ g/mol$ $= 40.00\ g/mol$
$m = 10.0\ g$	$m = ?$

solution: $n = \frac{m}{M} = \frac{10.0\ g}{98.08\ g/mol}$
$= 0.101\,96\ mol$

$$0.101\,96\ mol \times \frac{2\ mol\ of\ NaOH_{(aq)}}{1\ mol\ of\ H_2SO_{4(aq)}} = 0.203\,92\ mol$$

$$m = nM = 0.203\,92\ mol \times 40.00\ g/mol$$
$$= 8.16\ g\ \text{(3 significant digits)}$$

NOTES

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